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Are All Conservation Measures for Endangered Species Legitimate? Lines of Thinking With the European Hamster

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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 critically endangered rodent are the impoverishment and fragmentation of its habitat due to recent changes in agricultural practices and urbanization. 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 20 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 favorable to the species. Finally, we will highlight the links between European hamster conservation measures and wider problematics.

Keywords: population reinforcement, animal monitoring, agriculture, conservation measures, animal ethics, environmental ethics, *Cricetus cricetus*

INTRODUCTION

Conservation Measures for Animal Populations' Protection

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

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

However, in theory as in practice, whether natural or encouraged by humans, the restoration of biodiversity is not always self-evident. Indeed, when considering the animals and the ethics devoted to it, two concepts emerge. *Animal ethics* itself considers the animal as an individual and will then refer to the study of the moral responsibility of humans regarding animals taken as beings. It therefore poses "the classic questions of human duties toward animals, possible animal rights, and more generally, moral judgements to be made on our current treatment of animals" (Vilmer, 2008). Next comes *environmental ethics* which considers animal species as a whole, as building blocks of the ecosystems in which they live (Vilmer, 2008). These two ethics devoted to animals are different and are often brought to clash. Indeed, in a lot of situations, the interests of the individual appear to be opposed to the interests of the collective (e.g., population, species or ecosystem), since the protection of habitat may be the cause of deleterious actions on individuals. A perfect example is the plan of the Australian government to kill about 2 million feral cats by 2020 to preserve the native Australian fauna from a high level of predation due to felines. On the other hand, we cannot minimize the suffering of these cats that are shot, poisoned, or trapped. The case of Australia is extreme, but protecting biodiversity often leads to conflicts of interest between different social groups or ecosystem users. In France, a striking example of such conflicts is the return of the gray wolf (*Canis lupus*) from Italy, which has become a real "sensitive case" in the light of a very strong public opinion on this issue. Indeed, the French gray wolf case is a natural recovery and was not the subject of any reintroduction or population support plan. From an ecological point of view, a return to equilibrium is possible, but some believe that the wolf has not its place any longer because of its role of top-level predator and, thus, possible human competitor. Some lobbies do not hesitate to blame the carnivores for livestock slaughters leading to the rise of authorized shoots to 19% of the population of wolves in 2020.

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

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

The European Hamster Case: From Agricultural Pest to Flagship Species of Alsatian Biodiversity

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

Since the 1990 Bern Convention on the Conservation of European Wildlife and Natural Habitats, the European hamster is a strictly protected species (Annex II of Bern Convention). The common hamster was also included in the Annex IV of Habitats Directive (92/43/EEC) in 1993. Listed as Least Concern at the global level in the IUCN red list of Threatened Species, European scientists urgently requested its reclassification as Vulnerable species for many years (24th International Hamster Workgroup meeting; Surov et al., 2016). It is only in 2020 that the common hamster obtained the status of Endangered Species (Banaszek et al., 2020). Indeed, its range has declined in almost all areas it was present during the last century, especially in Western Europe but also more recently in Central and Eastern Europe (Stubbe and Stubbe, 1998; Surov et al., 2016). This is for example the case in Poland and the Czech Republic where populations have already significantly decreased (Ziomek and Banaszek, 2007; Tkadlec et al., 2012). The common hamster has already disappeared or regressed in many provinces of Eastern Europe and Russia where it was present, and if the evolution of populations continues in the same way, more than 70% of the population could disappear in these provinces (see Surov et al., 2016). In the western part, for example in the territory regrouping Belgium, the Netherlands and the German land of North Rhine-Westphalia, the hamster has declined by more than 99% in recent decades (La Haye et al., 2012). Agricultural practices, habitat fragmentation, fur trapping but also the impact of climate change and urban pollutions on the rate of reproduction of females have been identified as possible causes of such decline, even if the mechanisms are still difficult to identify for some (Stubbe and Stubbe, 1998; Monecke, 2014; Surov et al., 2016).

In France, the common hamster is only present in Alsace where hamsters' trapping and killing were common until the 1990s. Since one individual can hoard up to more than 10 kilograms of food in its burrow for hibernation (Nechay et al., 1977) and with the explosion of population documented during the twentieth century, one may understand that the European hamster was considered as an agricultural pest causing crop damage. At this time, farmers' children even earned pocket money for hamsters' fur. But during the 1970s, the habitat of the European hamster in Alsace began to change: agricultural practices evolved to single-crop farming, small villages expanded their urbanization plans, and more and more road infrastructures appeared dividing the landscape. All of these factors converged to disastrous consequences on hamsters' populations in Alsace. The common hamster has disappeared from the vast majority of its historical Alsatian range and is now only present in 18 municipalities compared to the 329 municipalities in 1972 (**Figure 1**).

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

Alsace is one of the most agricultural regions of France counting 40% of exploited lands (Agreste, 2020). The maize culture is one of the most important, not only for alimentation or seeds but also for biofuel or bioplastic (Méchin, 2011). Yet, it has been shown that maize as monoculture negatively impacts the survival of European hamsters not only by a lack of protective cover part of the year but also the behavior of mothers who killed their pups at parturition because of a lack of vitamin B3 and essential amino acids (Tissier et al., 2016a, 2017). Then, farmers were and are still the most impacted by conservation plans for the European hamster. However, the top-down policy-making process did not facilitate the relations between the different local actors since the animal as its protection was mostly felt as being imposed by others' decisions (politics and scientists) instead of being fully appropriated by farmers (Losinger et al., 2006; Méchin, 2013). Of course, the appearance of such group-conflicts and reactance processes are well-known to challenge the success of conservation plans (Lüchtrath and Schraml, 2015). On a larger scale, with larger mammals such as the European otter or the Eurasian lynx in France, the limiting factor appears to be only anthropic (Laurent, 2014). In these examples, fishers and hunters, respectively, do not accept the presence of those whom they regard as their direct competitors; stakeholders as well. This led to a major ethical issue: shall we favor humans or animals? Why is it so difficult to favor both? And more importantly, how do we even get to the question of our legitimacy to choose between both?

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

Studies and surveys of hamsters' populations have been carried out in several European countries including Germany, Poland, Czech Republic, Netherlands, Belgium, Austria, and France. The decrease of most of the populations led to the setting of protected areas. For example, in 2002, protected areas have been created in the Netherlands to reintroduce a hamster population in a favorable habitat (Müskens et al., 2005; La Haye et al., 2010). Such conservation plans (habitat protection and restocking measures) have also been carried out in Belgium (Verbeylen et al., 2007; Verbist, 2007), in Poland where wild animals from Czech Republic have been released as genetic support for the Polish population of Jaworzno (NAP 2019–2028), as well as in Germany (please see Weinhold, 2009 for an inventory of measures for each Federal states). In Alsace, population reinforcements of European hamsters are carried out since 2000 in three priority restocking areas with animals coming from breeding facilities. Releases performed in these areas lead to good results and hamster population grew the first years, but after this time hamster population decreased again and remained still low. The reasons for this partial failure seem to be an attraction of predators since hamsters were concentrated in a small area but were absent elsewhere (Villemey et al., 2013). Thus, these areas appeared for some as sanctuaries allowing protection managers to conduct their actions but also allowing the out-of-area farmers to be not concerned by the hamsters' protection following the Not-In-My-BackYard (NIMBY) principle (Méchin, 2011).

A second and more hand-in-hand—or at least holistic—strategy has been developed in France in 2013 with the beginning of the European granted LIFE+ Alister project. Until its end in 2019, different actors such as farmers, scientists, NGOs, and policymakers operated together not only to conduct discussions with hamster opponents, to breed and release individuals,

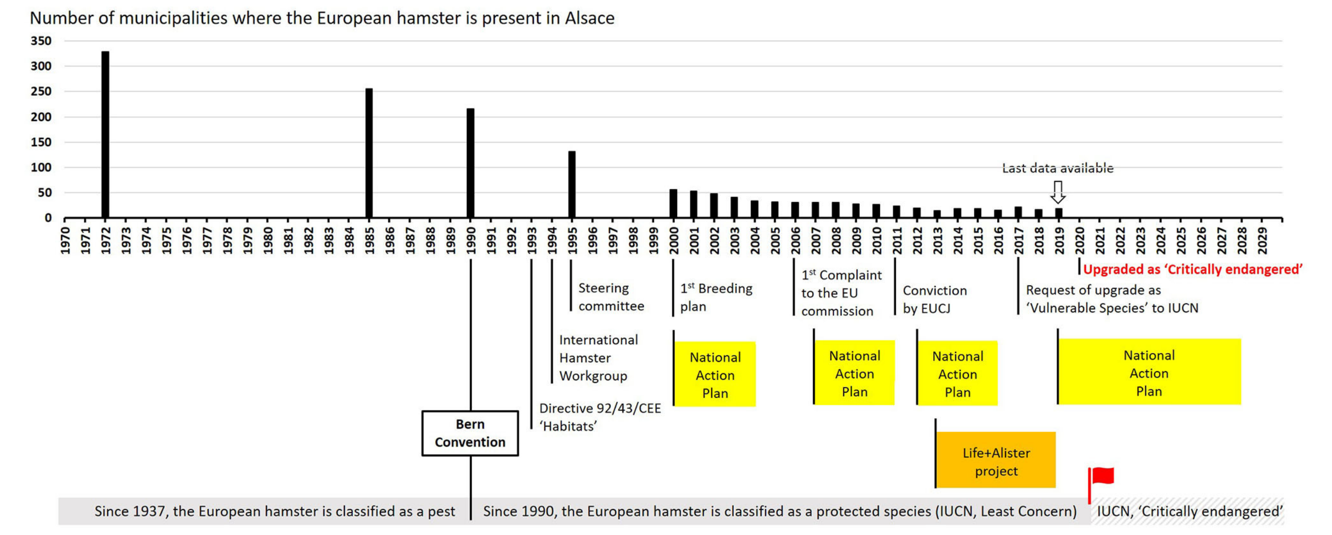

FIGURE 1 | Hamster conservation in Alsace: from the evolution of its presence to conservation plans between 1970 and 2028. Bars represent the number of municipalities where the European hamster is present in Alsace (France). The lower part of the figure represents the timeline of principal events concerning conservation measures and decisions for the species.

to study the ecological needs and biology of the species, but also to investigate the social dimension of the ongoing hamster conservation plan and improve the popularity of the species. A similar strategy was established in Germany with the Feldhamsterland program led by the NGO Deutsche Wildtier Stiftung which aims at targeting the best measures to protect the German hamsters' populations in collaboration with farmers and citizens.

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

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

POPULATION REINFORCEMENT

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

When talking about species conservation and especially with population reinforcements, genetic considerations have to be taken into account. Genetic diversity in populations has to be preserved to keep at a high level the fitness of the endangered species. For instance, it has been demonstrated that the habitat fragmentation of a small rodent-like the European hamsters can lead to low diversity in the population and threaten the species locally (Reiners et al., 2011). If genetic diversity decreases too much, it can be necessary to introduce animals from other phylogeographic groups to improve the survival chances of the population (Melosik et al., 2017). But to be successful, there are other several prerequisites for population reinforcements to fulfill. We will examine these prerequisites in the next section and expose what has been done for the European hamster and the results that were obtained.

Pre-releasing Requisites

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

Furthermore, all species cannot be released the same way. If we talk about mammals, it might seem easier to free thousands of rodents with high reproduction rates than a few large mammals whose reproduction rates are lower. At the individual level, most rodents will certainly not survive very long, but the species as a whole will probably make it out, whereas the large mammals will be more successful in the short term but with an uncertain future, mainly due to human pressure (notably illegal hunting). In the case of the French European hamster, it is clear that one may ask why such a rather prolific species (1–3 gestations a year of 3–12 young) remains endangered after 20 years of conservation measures and more than 3000 individuals released.

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

Reinforcement or Habitat Improvement: Where Is the Priority?

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

When populations have totally disappeared, the strategy may be different. Let us consider for example a well-studied species, the European otter (*Lutra lutra*). The French otter population underwent a continuous decline during the second part of the last century due to illegal hunting, habitat loss, and water pollution (Kuhn and Jacques, 2011). The reintroduction of animals from remote geographical origins is not recommended because of a risk of outbreeding depression and potential reduction of the fitness and long-term survival of the population (Randi et al., 2003). Thus, in this case, it appears more suitable to restore habitats and increase connectivity among residual animals via natural corridors. In the case of European otters, efforts to protect and rehabilitate such habitats have paid off, and otters recolonized areas throughout France over the past 20 years with regional variations (Lemarchand et al., 2016). But could this strategy of recolonization be applied to hamsters? Although the French hamster population is isolated from other residual European populations living in very different habitats, the solution could be similar on a local scale: protecting residual wild population nuclei and improving the surrounding habitats little by little to allow a natural recolonization. Again, the key issue is to change agricultural practices to find suitable crops for both hamsters (i.e., ecologically durable) and farmers (i.e.,

TABLE 1 | Pros and cons of the strategies considering different priorities for population reinforcement and habitat improvement.

	Population reinforcement while improving habitat	**Habitat improvement followed by population reinforcement**
PROS	May be seen as a first "trigger" step resulting in: - the maintenance of the population (no genetic loss) - a better perception/acceptance compared to a reintroduction if population extinct during this time - the maximization of the partners involvement (political and societal)	Derived from the necessity to solve the causes of the decline before reinforcing (otherwise it leads to a failure) resulting in: - a better perception of the conservation plan (seen as holistic instead of species-focused) - the maximization of the conservation efforts
CONS	Need to continue until the habitat has been sufficiently improved resulting in: - a possible long time before seeing positive or lasting effects of the reinforcements - a possible dispersion of actions and resources	May lead to the complete extinction of the population/species in the wild resulting in: - the ↓ of genetic diversity - the ↓ of politics stakes - the ↑ of administrative obligations - the ↓ of motivation of local actors - the ↓ of habits to live with this species

economically viable). This is what research is focusing on even if such strategy can take decades and requires considerable human and financial investments.

Problems Risen by Releasing Programs

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

Another problem that can be encountered with releasing programs is the regulation of predators. For prey species like the hamster, predation pressure is a key determinant of their survival (Kayser et al., 2003; La Haye et al., 2010; Villemey et al., 2013). Since many efforts are needed to breed and release animals, some people may ask for predator regulation to limit predation on released animals. Such a measure can be taken even though predation is a natural process, i.e., part of the food chain, and despite its low efficiency. Indeed, predator regulation has generally no significant and durable effect on the global predation rate of the prey (La Haye et al., 2008; Treves et al., 2016). The killing of predators can, however, be considered in programs like NAP since they result in the participation of many stakeholders, including hunters (Virion and Thouvenot, 2019). It is sometimes a wiser choice to consider this possibility—while trying to convince to never apply it—than showing strong opposition to it, leading to group reactance.

Results of Hamsters' Releasing Programs

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

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

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

IN SITU ANIMALS' MONITORING

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

Capturing and Tagging Animals

The capture of an animal is a way to gather many data or information about it. It can be weighed and measured, and samples of feces, hair, or blood can be taken for later analysis. At the same time, individual identification can be done to allow recognizing it later. Different methods can be used: (i) photo-identification, if the species have fur or skin patterns that differ from one animal to another like with some felines or amphibians; (ii) external tags like rings, bands, ear punches, toe clipping, tattoo; and (iii) internal systems like passive integrated transponders (PIT) for radiofrequency identification (RFID).

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

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

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

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

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

Transmitters to Follow Animals

Knowing the localization of specific individuals in the wild can provide valuable information, like home range or reproductive success. However, some ethical questions can arise with logger-transmitter equipment, especially intra-abdominal implantation of transmitters. The proximal issue with implantation is surgery that can cause suffering or even death. After surgery, implants can also affect the long-term behavior and the survival of animals. These questions have been assessed by Koehler et al. (1987) in a study carried out on four species of small rodents: they show a mortality risk with surgery (14% in their study but they indicate how to improve it), but a good survival after the release (more than 94% after 1 month). Nowadays, survival after surgery is now much better and can reach 100% after implantation of transmitters for hamsters (Capber, 2011). Furthermore, some of the transmitters in Koehler et al. exceeded 10% of the mass of animals while it is now recommended not to exceed 3–5% (Macdonald and Amlaner, 1980; Theuerkauf et al., 2007). In France, European hamsters are only implanted when their body mass exceeds 150 g. The transmitter weighing 6.5 g does not therefore exceed 4.3% of the body mass of the hamster and, thus, never exceeds the recommended range. It explains partially the good tolerance observed in the field. Furthermore, the transmitters do not seem to impair gestation (Capber, 2011). Thus, it is possible to implant loggers and transmitters without marked impact on the survival of individuals or on a population. However, since it is an invasive protocol—even moderate—it has to be used when expected benefits are high enough for the monitoring of equipped individuals, and only when necessary.

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

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

MODIFICATION OF AGRICULTURAL PRACTICES

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

What Are Hamsters' Needs?

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

The crop in which they live provides hamsters also a protective cover against predators. However, this cover can be reduced or removed by the work of farmers, like harvesting, mowing, or plowing, resulting in increased exposure to predation (La Haye et al., 2010, 2014). It has also been observed that such removing of the cover leads to an increased emigration of hamsters out of the concerned plots, threatening their survival (Kayser et al., 2003; Kourkgy, 2019).

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

How to Implement Suitable Habitats?

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

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

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

What kind of agriculture functioning at a large scale could provide the different services and integrate the methods exposed above? Some of them can be filled with organic agriculture, which is moreover already well integrated by citizens. However, it still usually (but not always) works with monospecific crops and bare soils, especially for weed control. Other types of agriculture are rising and aim to develop healthier soils and more biodiversity in agricultural systems. We can find it under different names like soil conservation, conservation agriculture, agroecology, biodiversity-based agriculture, or ecologically intensive agriculture. Even if there are many variations in concrete applications of these innovative agricultures, they all rely on the same principles of improving soil quality, increasing the diversity of plants and habitats along time and space, and integrating in a holistic approach the relations between the multiplicities of organisms living in the ecosystem (Duru et al., 2015; Wezel et al., 2018; Chabert and Sarthou, 2020).

Why Is It so Difficult to Modify Agricultural Practices?

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

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

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

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

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

Finally, the last hurdle we can talk about is associated with social perception. In our societies with task repartition, we delegate to farmers the production of our food. In that context, we can wonder if it is the consumers and not the farmers that would have the biggest responsibility in the ecological implications linked to agriculture. On one hand, farmers think usually that their actions are limited since they have to follow the law of the market, so it should be consumers that have to pay the right price if they want ecology to be considered. On the other hand, consumers think that farmers are responsible for diverse pollutions and should take the responsibilities linked to what and how they produce. Thus, an opposition develops between different groups: consumers and farmers, but also environmentalists, hunters, scientists, politics, *etc.* This is linked to the social identity theory and psychological reactance, as illustrated by Lüchtrath and Schraml (2015) in the context of hunters' opposition to large carnivores. They show that the different groups are in reactance with what can be proposed by others, to protect their social identity. Thus, it seems particularly important to build positive relationships to avoid such reactions of different groups of actors.

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

The European Union: A Leverage or a Barrier for the Conservation of the European Hamster?

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

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

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

What About a Successful Increase in the Population?

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

Other Issues, Same Problems, Same Solutions

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

The European hamster is not the only species endangered in agricultural areas. Many farmland bird populations are decreasing since several decades (Donald et al., 2001; Heldbjerg et al., 2018; Stanton et al., 2018; Department for Environment Food Rural Affairs, 2019; Gaget et al., 2019). Invertebrate species are also concerned, with insects suffering a massive drop potentially linked to unsustainable agricultural practices (Benton et al., 2002; Shortall et al., 2009; Hallmann et al., 2017). Therefore, conservation measures are widely developed to protect farmland species or taxa, involving various stakeholders. In France, this can be illustrated by the development of different specific national action plans (NAP) like the one for the little bustard (*Tetrax tetrax*) (Poirel, 2019), the one for pollinators (Gadoum and Roux-Fouillet, 2016) or the one for adventive plants (Cambecèdes et al., 2012). During the last European hamster NAPs, conservation measures for hamsters and associated innovative practices have been identified to be highly beneficial not only for hamsters but also for a lot of other species including the above-cited ones (Wilson et al., 2005; Liu et al., 2015; Norris et al., 2017; Zellweger-Fischer et al., 2018).

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

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

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

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

If innovative agricultural practices can help to adapt to climate change, they can also be beneficial to limit it. As explained previously, soil improvement is a key factor for the agricultural systems, and it relies on the increase of soil organic carbon. This organic carbon comes from the photosynthesis of plants, taking carbon dioxide from the air. This mechanism is important enough to have a significant effect on atmospheric CO_2 concentration. This is for example what is promoted through the 4 per 1000 initiative since an increase of soil carbon of 0.4% each year in the 30–40 first centimeters of all agricultural soils would allow compensating global annual CO_2 emissions (Rumpel et al., 2020). This does not mean that we found the solution to solve the atmospheric CO_2 problem or that we have not to reduce carbon emissions, but it shows that agriculture can significantly contribute to slow down the global change.

CONCLUSION

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

AUTHOR CONTRIBUTIONS

FK and MP equally contributed to this work as the first author. All authors brought constructive thoughts and participated in the elaboration of this review. All authors contributed to the article and approved the submitted version

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