



Applicability of the ecological intensification concept to large carnivores in agricultural landscapes

Deliverable D3.7

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SHOWCASE

SHOWCASing synergies between agriculture, biodiversity and Ecosystem services to help farmers capitalising on native biodiversity



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Preface

This report presents a synthesis of the literature on ecosystem services provided by large carnivores to agriculture. Further, it presents findings from expert interviews that we conducted to assess whether there is a rationale that could induce farmers to shift their management systems toward ecological intensification with a role for carnivores. An acknowledgement of ecosystem services provided by carnivores for agriculture would mark a first step toward a possible shift to ecological intensification with a role for large carnivores.

The report is part of the project “SHOWCASing synergies between agriculture, biodiversity and Ecosystem services to help farmers capitalising on native biodiversity” (SHOWCASE). SHOWCASE is dedicated to gathering further evidence on the ecosystem services provided by increased levels of biodiversity and identifying incentives for farmers to uptake biodiversity-friendly farming practices across Europe. The project receives funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No.862480. In particular, this report fulfils Deliverable 3.7 within SHOWCASE “Policy guidelines on best practices for conflict resolution between large carnivores and livestock farmers”. The team of researchers working on this task would like to extend their thanks to all interview participants for their time and openness to our questions.

Key takeaway messages

- Large carnivores can provide a range of regulating and cultural ecosystem services to agriculture.
- Interviewees report that farmers hardly perceive or appreciate any beneficial ecosystem services provided by carnivores.
- Farmers’ capability to implement on-farm measures in support of carnivores is low.
- Interviewees are not aware of any major societal demand for ecosystem services provided by large carnivores to agriculture.
- Based on the interview results, there is currently little scope for a rationale based on which to concede large carnivores a role in ecological intensification.
- A step forward would be to foster a balanced societal understanding of the ecosystem services and disservices provided by large carnivores to agriculture.

Summary

In task 3.7 of the Showcase project, we sought to answer three questions. The first was which ecosystem services carnivores can provide to agriculture. The second question was whether the ecological intensification concept can potentially be applied to large carnivores, in particular lynx, bears, wolves, and jackals. The third question was whether, based on our findings, we can identify leeway for integrating the ecological intensification concept into existing policies for resolving carnivore-livestock conflicts in order to improve their efficiency and effectiveness.

Our literature review identifies three major types of ecosystem services that large carnivores can provide to agriculture. **Density mediated regulating services** (regulation of wild ungulates and wild boars that cause damage to crops and spread diseases, as well as ensuing nutrient dynamics, erosion control and water quality improvements), **behaviorally mediated regulating services** (carnivore presence, real or simulated through scent sprays, induces risk effects among prey species that can help steer wild ungulates away from crops), and **cultural services** (preservation of a culture of co-existence, including mentalities but also more tangible things such as the sustainment of livestock guardian dog breeds).

We conducted expert interviews in Romania, Estonia, Hungary, Spain and Switzerland with representatives of farmers' associations, environmental NGOs and government authorities to investigate whether there is a rationale that could induce farmers to shift their management systems toward ecological intensification with a role for carnivores. In the interviews we focused on four aspects that have previously been identified as relevant for shifts to ecological intensification: farmers' motivation and ability as well as societal demand and legitimation.

In terms of **motivation**, the interviewees generally stated that farmers hardly perceive any beneficial ecosystem services provided by carnivores. The exceptions that were mentioned seem to follow a pattern of decreasing appreciation of carnivores' ecosystem services with increasing agricultural productivity. Most interviewees could not see a role for local communities in fostering farmers' motivation and ability in this context. The only exceptions mentioned were small touristic activities focused on carnivores that may unfold into moral and economic support. Farmers' **capability** to implement measures in support of carnivores was generally deemed to be very low with no scope for on-farm measures in favor of carnivores. Across all study countries, the respondents explained that livestock protection requires specific knowledge, financial resources, time and willingness. Generally, the NGO representatives were more optimistic about limiting further predation should carnivore numbers increase than the other respondents.

With few exceptions, the interviewees across the study countries stated that there is no major **societal demand** for ecosystem services that large carnivores provide to agriculture. However, many explained that there are differences between urban and rural citizens. Societal demand for carnivores' regulation of prey species is limited to a few regions where prey species are insufficiently regulated by hunters.

Finally, on the topic of **legitimate measures** the respondents mentioned that farmers can ask for lethal control of a large carnivore as far as it complies with the national and EU legislation. Switzerland is an exception: farmers were said to only have the option to implement protective measures or to use the democratic tools to try to change the law. Asked about farmers' influence on carnivore policies, the interviewees in all study countries responded that farmers have moderate to high leverage in the carnivore policy debates.

Based on our findings, we conclude that apart from the obvious disservices, carnivores can also provide a range of ecosystem services to agriculture. However, without farmers' motivation and ability as well as limited societal demand and legitimate measures there is currently little scope for a rationale based on which to concede large carnivores a role in ecological intensification. This also limits the potential to improve the efficiency and effectiveness of existing policies through an integration of the ecological intensification concept. A first step forward could be to foster a balanced societal understanding of the ecosystem services and disservices provided by large carnivores to agriculture.

List of abbreviations

EU	European Union
NGO	Non governmental organization

1 Introduction

In Europe, as elsewhere, farming systems evolved over centuries that were intimately tied to ecosystem services provided by biodiversity. Large carnivores formed an integral part of this biodiversity until the nineteenth and early twentieth century (Boitani and Linnell 2015). Aiming at obtaining higher yields and profits, the advent of modern agriculture has led to deep alterations of ecosystems (Sánchez-Bayo and Wyckhuys 2019; Tscharntke et al. 2021). For example, the use of agrochemical inputs has succeeded in increasing yields, but comes at the expense of decimating biodiversity (Geiger et al. 2010; Emmerson et al. 2016). Persecution, a depletion of prey species and habitat conversion have led to the decline in numbers and spatial spread of large carnivores, which previously roamed large parts of Europe (Boitani and Linnell 2015). In recent years, large carnivores have started to regain ground (Chapron et al. 2014). Today, Europe is home to around 1 thousand wolverines (*Gulo gulo*), 8-9 thousand Eurasian lynx (*Lynx lynx*), 17 thousand wolves (*Canis lupus*), 17-18 thousand brown bears (*Ursus arctos*), and 97 – 117 thousand golden jackals (*Canis aureus*) (LCIE 2021). Conventionally, jackals are not counted to the group of large carnivores. We include them here given their importance as a carnivore species that is rapidly expanding (Tóth et al. 2009; Spassov and Acosta-Pankov 2019; Stronen et al. 2021).

In view of the downward spiraling effects of conventional agriculture on biodiversity, SHOWCASE explores alternative approaches that can meet society's needs in terms of food security as well as intact ecosystems and ecosystem service provision. In task 3.7 of SHOWCASE, we investigated which ecosystem services large carnivores potentially can provide to agriculture and whether the ecological intensification concept can be applied to large carnivores, in particular lynx, bears, wolves, and jackals. A further question is whether the ecological intensification concept could complement or even improve the efficiency and effectiveness of existing policies for resolving carnivore-livestock conflicts. With ecological intensification, the idea is to maintain yield levels at least constant but to actively integrate ecosystem services provided by biodiversity into farming systems in order to avoid damaging the environment (Doré et al. 2011; Bommarco et al. 2013; Kleijn et al. 2019).

Our approach is based on a literature review and expert interviews in five countries of Europe along an agricultural productivity gradient (using the gross value added per agricultural labor force unit as indicator). The study countries are marked in red in Figures 1 and 2 and represent different segments along the agricultural productivity – carnivore gradient. Eurasian lynx (*Lynx lynx*) are present in Estonia, Romania, Switzerland and at least occasionally in Hungary. Spain hosts a population of Iberian lynx (*Lynx pardinus*). Wolves (*Canis lupus*) are also present in all of our study countries. Romania, Estonia and Spain additionally host resident bears (*Ursidae*). Golden jackals (*Canis aureus*) are resident in Hungary, Romania and Estonia.

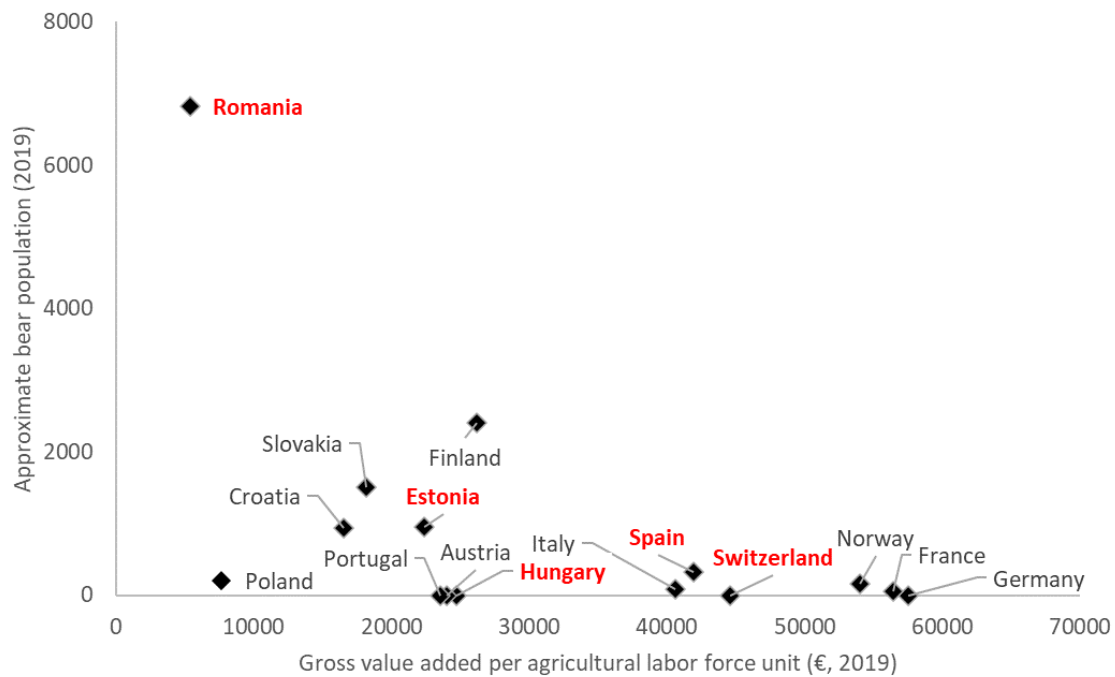


Figure 1: Agricultural production intensity and approximate bear population

Data sources: (Euro Large Carnivores 2022; EUROSTAT 2022a, 2022b; BFS 2021)

Note: For many countries, the Euro Large Carnivore Factsheets provide ranges as estimates of carnivore numbers. For simplicity and illustration purposes, we present the middle values of these ranges as point estimates.

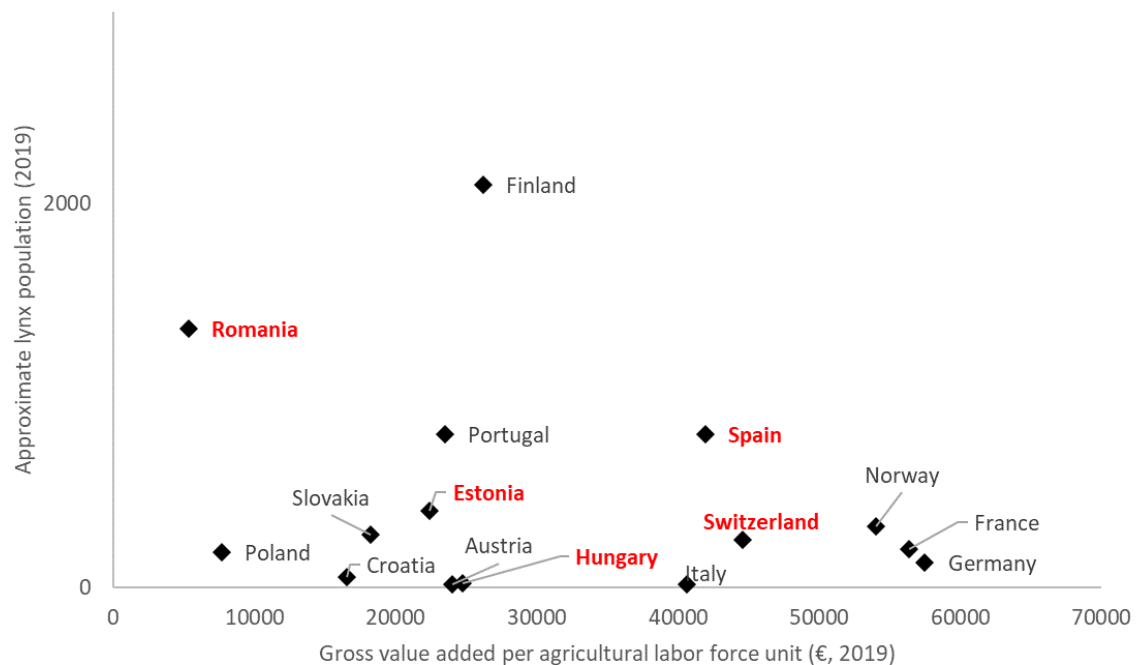


Figure 2: Agricultural production intensity and approximate lynx population

Data sources: (Euro Large Carnivores 2022; EUROSTAT 2022a, 2022b; BFS 2021)

Note: For many countries, the Euro Large Carnivore Factsheets provide ranges as estimates of carnivore numbers. For simplicity and illustration purposes, we present the middle values of these ranges as point estimates.

2 Methods

Our research in task 3.7 started with the development of a conceptual framework on determinants for farmers' decision to shift to ecological intensification. We complemented this framework with findings from a literature review on ecosystem services that large carnivores provide to agriculture and the efficiency and effectiveness of damage mitigation measures. The review of ecosystem services provided specifically to agriculture deviates from our initial plan to do a broad review on carnivores' services and disservices. The reason for the change of plan was the publication of a new paper that already presents a broad review of carnivores' ecosystem services and disservices (Rode et al. 2021). Repeating such a review would have been redundant. As illustrated in Figure 3, in a next step we conducted expert interviews and synthesized our findings to derive policy recommendations. The conceptual framework and the interview questions are presented in more detail below.

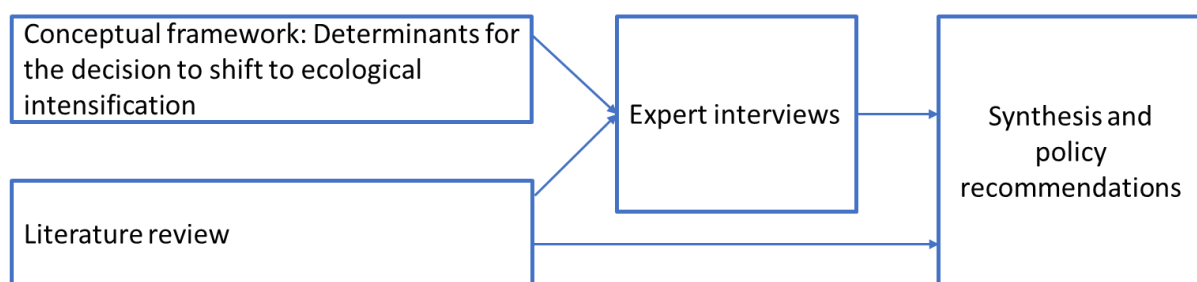


Figure 3: Overview of the methodological approach

2.1 Conceptual framework

For farmers accustomed to conventional farming, shifting their production system to ecological intensification may be a difficult decision, even if this involves only rather non-contentious species such as insects, spiders and earthworms. From a farmers' perspective, there can be various strings attached, including higher opportunity costs than benefits, uncertainty related to the efficacy of the concept and concern over variability of the outcomes under differing external (weather) conditions (Kleijn et al. 2019). Runhaar et al. (2017) and Schoonhoven and Runhaar (2018) argue that it takes a combination of motivation, demand, ability, and legitimation for farmers to accomplish this shift in their production systems. We take these four criteria as a starting point to empirically explore if there is any avenue for a rational based on which to concede large carnivores a role in ecological intensification (see Figure 4).

Related to the agricultural productivity-carnivore gradient (see Figure 1 and Figure 2 above), we hypothesize that motivation, ability, and demand decrease with an increase in agricultural productivity. This is because we assume that in strongly modified landscapes with high agricultural productivity substitutes for ecosystem services provided by carnivores are readily available that come at lower short-term cost. Given that most of the carnivores covered in this study are subject to the Bern Convention, we expect little variation in the findings on legitimation.

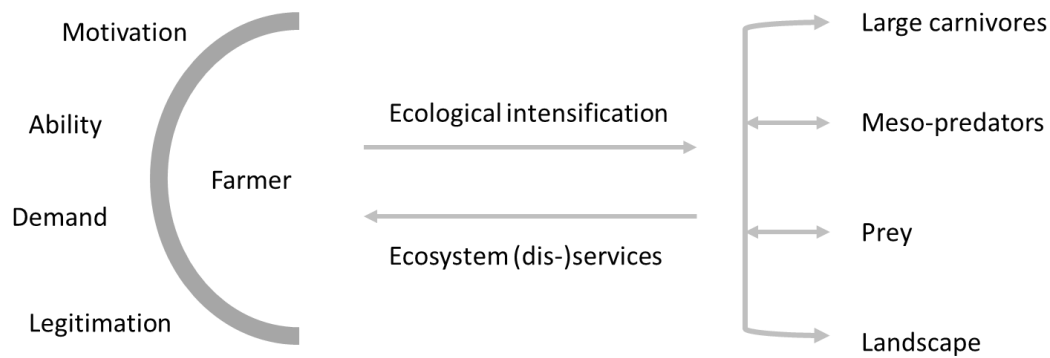


Figure 4: Framework on carnivore-based ecological intensification

Source: Authors' drawing

Motivation to shift farming practices toward ecological intensification can arise if the expected net benefits of the shift are expected to outweigh those of current practices. Although context dependent, often ecological intensification can give rise to multiple benefits (Garibaldi et al. 2019). Foremost, motivation may relate to benefits in terms of economic profitability. Provided there is societal demand and political will, the question of economic profitability can be solved by means of incentive payments (Recio et al. 2020). Yet, other benefits apart from economic profitability may be equally important for a farmer's motivation (Kerneck et al. 2021). For our context, the key question is whether farmers see tangible benefits for agriculture in carnivores' ecosystem services, in particular the control of ungulates and meso-predators, a decreased risk of disease spillovers from ungulates to livestock, or the preservation of traditional herding systems.

Concerning **ability**, humans can choose between two types of measures to impact carnivores: lethal control or measures to impact carnivores' behavior (Ordiz et al. 2013; Kuijper et al. 2016). Farmers can thus directly influence the density of carnivores by hunting or allowing others to hunt the carnivores and their prey species on their land. Moreover, farmers can impact the extent of available habitat for carnivores and prey species on their property.

Apart from lethal removal, farmers can influence behavior, e.g., by managing the landscape in a way that creates favorable conditions for carnivore's hunting success. In landscapes that host large carnivores, prey species often adapt their behavior to the perceived risk, seeking or avoiding open spaces such as fields, depending on the carnivore species' hunting strategy and their own escape strategy (Kuijper et al. 2016). Thus, providing habitat for carnivores can in some cases help change wild ungulates' behavior to the benefit of agriculture. However, a premise of ecological intensification is that agricultural yield should remain at least constant while actively integrating ecosystem services provided by biodiversity into farming systems. This means that the question addressing farmers' ability to implement measures to achieve the shift toward ecological intensification needs to cover two aspects. Firstly, farmers' capability to implement density or behaviorally mediated measures in support of carnivores and secondly, farmers' capability to prevent negative implications such as predation on livestock.

In terms of efficiency and effectiveness of damage mitigation, for the European context Oliveira et al. (2021) reveal that electric fences, visual and sound deterrents, livestock guarding dogs, and shepherds are among the most effective options. Further effective measures include the prevention of access to anthropogenic food sources, and damage compensation. Increasing the food availability for carnivores, and information dissemination were found to be less effective. These findings for Europe are in line with experiences made elsewhere. In a global review, Lorand et al. (2022) assert that non-lethal interventions are more effective in conflict mitigation than translocation and killing of large carnivores.

Societal **demand** for large carnivores' and their ecosystem services can be multifaceted with different segments of society advocating for or against carnivores for various reasons. For the

purpose of this study, we focus on asking stakeholders whether there is societal demand for the ecosystem services that large carnivores provide to agriculture, such as the provision of a more balanced ecosystem, including the mitigation of any disservices provided by wild ungulates or meso-predators. Given that large carnivores may provide cheaper and more effective control of ungulates and meso-predators than control programs administered by humans (Prugh et al. 2009), we asked who (if anyone) is otherwise responsible for their control in the absence of carnivores.

The prevailing governance framework determines which set of measures are **legitimate** for a farmer to implement. The set of legitimate measures can be larger or smaller than the set of measures that an individual farmer is able to implement. Among the large carnivores addressed in this paper *Lynx pardinus*, *Ursidae*, and *Canis lupus* are listed as strictly protected fauna species in Annex II of the Bern Convention and *Lynx lynx* are listed as protected fauna species in Annex III. Golden jackals are not listed in either Annex II or III of the Convention. The key questions for our context are thus to what extent a farmer can effectuate a permit for lethal control of a large carnivore and how influential farmers are in the political debate on large carnivore policies.

2.2 Literature review

To synthesize the evidence base on large carnivores as direct or indirect ecosystem service or disservice providers, we conducted a literature search of academic and grey literature. The objective was to provide a narrative review of case studies (rather than a systematic review) on ecosystem services provided by large carnivores to agriculture. We first used the search engine 'Web of Science' for a broad search. We used search terms composed of key words including 'large carnivore' as well as specific carnivore names combined with 'ecosystem services' as general term and more specific ecosystem service keywords (see the search protocol in Table 1, updated in April 2024). After this broad search, we pursued a snow-ball approach, i.e. followed-up on references that were provided in relevant papers. To complement the review with literature specific to our case study countries, we used the search engines 'Science direct' and 'Google scholar' for selected specific terms.

Table 1: Search protocol

Search terms	Records from Web of Science
"large carnivore" AND "ecosystem services"	14
"canis lupus" AND "ecosystem services"	16
"canis aureus" AND "ecosystem services"	5
"lynx lynx" AND "ecosystem services"	2
"lynx pardinus" AND "ecosystem services"	1
"ursus arctos" AND "ecosystem services"	8
"canis lupus" AND "erosion"	15
"canis lupus" OR "canis aureus" OR "lynx lynx" OR "ursus arctos" OR "lynx pardinus" AND "disease control"	15
"canis lupus" OR "canis aureus" OR "lynx lynx" OR "ursus arctos" OR "lynx pardinus" AND "erosion control"	0
"canis lupus" OR "canis aureus" OR "lynx lynx" OR "ursus arctos" OR "lynx pardinus" AND "cultural service"	0
"canis lupus" OR "canis aureus" OR "lynx lynx" OR "ursus arctos" OR "lynx pardinus" AND "risk effects"	21
97 records in total (- 6 doublets) -> 91 records without doublets	
91 records' titles screened -> 15 records excluded based on irrelevant titles,	

76 records' abstracts screened -> 53 excluded based on irrelevant abstracts & 4 records excluded after reading
19 records read and included in the review
22 additional records from snowball sampling or additional searchers for case studies
41 records in total

2.3 Expert interviews

Initially, our plan was to conduct in-person focus group discussions. Due to the pandemic and certain concerns over the dynamics that can evolve in focus group discussions, we decided to do remote expert interviews instead. In several countries it was extremely difficult to find experts that were willing participate in an interview, despite guaranteed anonymity. The carnivore debate is so heated and hostile in some countries, that stakeholders were reluctant to talk even to researchers. Despite these difficulties we managed to conduct an interview with a representative of a farmer's association, a representative of an environmental NGO, and a representative of a government authority dealing with carnivore management in each of our case study countries. In Estonia we even managed to conduct four interviews (2 with NGO representatives). The interview questions listed in Table 2 were based on the framework presented above. The interviews were conducted in 2022 by the authors in the interviewees' native languages and the findings were later translated to English for the analysis.

Table 2: Questions asked in the expert interviews.

Question	
1. Do you think that farmers perceive benefits for agriculture from the ecosystem services provided by large carnivores? Examples of such benefits are the control of ungulates, wild boar (including limiting the spread of swine flu) and meso-predators, a decreased risk of disease spillovers from ungulates to livestock, or the preservation of traditional herding systems.	Motivation
2. Can local communities foster the motivation and ability of farmers who are implementing measures to enhance carnivores and the ecosystem services they provide?	
3. Focusing only on capability, in your opinion, are farmers' capable of implementing measures that could support carnivores? For example, by not applying for permits for lethal control of carnivores, but rather implementing damage prevention measures (e.g. use of electric fences, specialized guardian dogs, night enclosures, permanent presence of shepherds, etc.) or by creating carnivore-friendly habitat on their property? In other words, if a farmer would want ecological intensification with a role for carnivores, could he/she take such meaningful actions?	Ability
4. Do you think farmers have the capability to prevent additional predation on livestock if large carnivore numbers were to increase? Please elaborate.	
5. In this country, who is responsible for the control of ungulates, wild boars and meso-predators (e.g. foxes)? Is this / Are these actor(s) efficient in controlling these species?	Dem and

6. In your opinion, is there societal demand for or appreciation of the ecosystem services that large carnivores provide to agriculture, such as the provision of a more balanced ecosystem, including the mitigation of any disservices provided by wild ungulates or meso-predators? Please provide potential differences (if any) between urban (people not having direct contact with large carnivores) and rural societies (living in the proximity of large carnivores)	Legitimation
7. In your country, to what extent can a farmer ask for lethal control of a large carnivore?	
8. In your opinion, how influential are farmers in terms of large carnivore policies/ management decisions (e.g. low / medium / high influence, please elaborate...).	

3 Results

3.1 Ecosystem services provided by large carnivores to agriculture

Based on a thorough literature review, Rode et al. (2021) present an overview of social impacts provided by large carnivores to different segments of society, including farmers, hunters, tourism operators and tourists, as well as local people. The main benefits they identify related to farming are less damage to trees and crops as well as disease control due to carnivores' control of ungulates. In terms of disservices to farming they mention disease transmission from carnivores to livestock, damage cost from predation and cost of measures to prevent predation, loss of employment in farming and herding, as well as negative emotions and health effects due to coping with risks of predation and loss of livestock. Given our interest in ecological intensification, below we focus on the services that large carnivores provide to farming, which mostly fall into the categories regulating and cultural services.

3.1.1 Density mediated regulating services

Regulating services often do not arise directly from carnivores, they rather unfold through density- and behaviorally mediated effects on prey in trophic cascades (Ripple et al. 2014). In the European farming context, large carnivores' density regulation of wild ungulates is of particular interest. Wild ungulates can give rise to various ecosystem disservices including, vegetation damage, disadvantageous soil alterations, crop damage, grazing competition with livestock, direct damage to farmed animals, or disease transmission to livestock (Pascual-Rico et al. 2021). Similarly, carnivores can contribute to controlling wild boars (*Sus scrofa*) which can cause substantial damages to agriculture. This includes a decrease in the risk of disease spill-overs from wild boars which are susceptible to animal tuberculosis that can infect cattle (Tanner et al. 2019). Large carnivores may also directly, or indirectly through meso-predators, regulate rodents which can host various zoonotic diseases (Ostfeld and Holt 2004). In this context, jackals as meso-predators have an ambivalent role. On the one hand, given that they prey on rodents, they can contribute to the spread of severe zoonotic diseases such as Alveolar echinococcosis and cystic echinococcosis or diseases caused by *Dirofilaria immitis* (Tolnai et al. 2014; Balog et al. 2021). On the other hand, their control of rodent populations can contribute to reducing damage to agricultural crops (Ćirović et al. 2016). Moreover they can significantly contribute to waste management by removing livestock carcasses and other animal waste, especially in areas with poor regulations on the disposal of slaughter remains and limited populations of obligate scavengers (Ćirović et al. 2016; Lange et al. 2021). However, in the wake of the EU sanitary regulation on livestock disposal, this ecosystem service became redundant in many areas (Lagos and Bárcena 2015). In Spain, farmers are often critical to facultative scavengers, such as wolves and bears, but appreciate

the ecosystem services and lack of predation threat provided by obligate scavengers, such as vultures (Aguilera-Alcalá et al. 2020).

Predation by large carnivores as well as scavengers further contributes to nutrient dynamics across landscapes with impacts on soil nutrient content and biological productivity (Schmitz et al. 2010; Moleón et al. 2014; Morris and Letnic 2017). In the context of North American national parks, carnivore abundance, mediated through their impacts on ungulates, can also be associated to erosion control and improvements of water quality (Beschta and Ripple 2006; Beschta and Ripple 2008, 2009, 2012, 2015; Ripple et al. 2015; Beschta and Ripple 2019). Although erosion control and water quality are key to farming, it is unclear to what extent these findings can be generalized to regions outside of parks.

3.1.2 Behaviorally mediated regulating services

Apart from lethal regulation of prey densities, the presence of large carnivores creates a 'landscape of fear' for prey species and induces antipredator behavior called risk effects (Moll et al. 2017). Examples of such risk effects include increased vigilance, a decrease in foraging time, moving from qualitatively and quantitatively better to poorer but safer foraging sites, or changes in group size (Creel et al. 2005). However, risk effects are context specific and can depend on whether the specific carnivore species uses a cursorial or ambush hunting strategy and the prey species' escape strategy (Kuijper et al. 2016; van Beeck Calkoen et al. 2021). Human presence can interact with these effects (Kuijper et al. 2015; Proudman et al. 2021). For example, in landscapes with human and large carnivore presence, the risk effects of human activities have been found to outweigh those of the carnivores (van Beeck Calkoen et al. 2022). The benefits of risk effects to farming have been long noticed and have been made commercially available as off-the-shelf spray or dusted scent of 'meat and blood' or 'urine, hair and feces of predators' (Guerisoli and Pereira 2020). Interestingly, the latter were found to be the most effective in a comparison of repellents (Boitani and Linnell 2015; Guerisoli and Pereira 2020). Lion and tiger fecal odors were found to be effective in changing the grazing patterns of feral goats in Australia (Cox et al. 2012). Feral goats are detrimental to agriculture because they compete for fodder with livestock and contribute to environmental degradation.

3.1.3 Cultural services

Cultural ecosystem services provided by carnivores to farming systems pertain to the preservation of a culture of coexistence between humans and large carnivores and an understanding that a certain extent of frugality is necessary for the sake of conservation (Martínez-Abraín et al. 2021). In the absence of large carnivores, approaches and mentalities supporting coexistence run the risk of falling into oblivion (López-Bao et al. 2017). For example, in large parts of Europe, knowledge on the use of livestock guardian dogs was forgotten during the absence of large carnivores (Gehring et al. 2010). In Romania this traditional ecological knowledge was maintained due to the uninterrupted presence of carnivores and the use of livestock guardian dogs in the Carpathians (Ivaşcu and Biro 2020) and can now be used to advise herders in other countries.

However, it is important to recognize that the composite impact of large carnivores on ecosystems can differ by species and ecosystem (Estes et al. 2011). In some areas, especially in southern Europe, bottom-up regulation of ungulates through diseases and forage availability may be more relevant than top-down regulation through carnivores (Martínez-Abraín et al. 2021). Moreover, there are question marks on the symmetry to which these ecosystem services previously provided by large carnivores' will be restored when they recolonize their former ranges (Alston et al. 2019).

3.2 Findings from the expert interviews

Below, we present the findings from the expert interviews along the lines of the conceptual framework that is based on Runhaar et al.'s (2017) elements of the rationale for a shift toward ecological intensification.

3.2.1 Motivation

The first question was whether the interviewees think that farmers perceive benefits for agriculture from the ecosystem services provided by large carnivores. Most interviewees from all study countries stated that farmers hardly perceive any such benefits by carnivores for agriculture. The perception of damages caused by large carnivores generally prevails. However, some exceptions were mentioned. In Romania, all interviewees said that farmers do experience the benefits of large carnivore presence, such as the limiting of ungulates and the related increase of carrying capacity for livestock and decreased damages to crops, but large carnivores are not esteemed for these services. However, in areas where bears are present in large numbers, they can also damage crops themselves. In Estonia, an interviewee mentioned that farmers perceive benefits provided by carnivores and explained that in regions with threshold levels on carnivores, farmers have contracts with hunters instead. According to the interviewees, further benefits perceived by farmers include golden jackals' regulation of game, wild boar and common vole populations in Hungary or carnivores' control of wild ungulates that share diseases such as brucellosis or tuberculosis with domestic ungulates in Spain. In Spain, an interviewee remarked that managers of hunting reserves became more favorable of Iberian lynx once the species became established in their area and the managers observed the lynxes' control of other meso-predators. The interviewee further asserted that while most farmers and ranchers are aware of the existence of benefits associated with the presence of large carnivores, the perception of the species is too polarized and conditioned by public discourses which leads to a dilution or insufficient consideration of possible positive effects compared to the damage caused by the species. In Switzerland, none of the interviewees could provide examples in which farmers perceived benefits from ecosystem services provided by carnivores. However, large carnivores are not present in the country's main agricultural area. Roe deer were mentioned to become more aggressive and thus problematic in the presence of wolves. According to an interviewee, farmers argue that wolves are a threat to biodiversity because in their presence, alpine herding systems that host a lot of biodiversity are abandoned. Further, according to an interviewee, some farmers argue that Switzerland is not appropriate for wolves in terms of animal welfare due to the high human population density and risk of car accidents. If at all, lynx were conceded a role in forests. One expert explained that ecosystem services may be relevant at larger scales but not noticeable for an individual farmer. For local people, individual cases e.g. of livestock predation, matter more than the big picture.

A second question was whether local communities can foster the motivation and ability of farmers who are implementing measures to enhance carnivores and the ecosystem services they provide. In Romania, Estonia and Hungary, the interviewees did not see such a role for communities. However, in Hungary, there was mention of two mayors who are trying to create a tourist attraction out of the carnivores' presence. In Spain, opinions on the role and competencies of communities diverged. Members of the tourism sector were mentioned as potential supporters, both in moral and economic terms. For example, they can purchase local products, facilitate activities, create a positive reputation and encourage the motivation of farmers and ranchers. All interviewees in Switzerland negated that communities could take a supportive role and put forward that no one wants to foster large carnivores. Any move in this direction would be quickly stifled.

3.2.2 Ability

To learn more on the aspect of ability, we asked the interviewees whether a farmer could take meaningful actions if she/he would want ecological intensification with a role for carnivores. In Romania, interviewees said that night enclosures and shepherds with (often untrained) dogs

are common and part of the tradition. However, demand for shepherds is increasing and it is becoming challenging to find good shepherds. Other prevention measures such as specialized guardian dogs and electrical fences are seen with reluctance by farmers because they need to be self-financed by farmers without support by the authorities. As one interviewee put it, the advantage of Romanian shepherds is that they for centuries are accustomed to cohabitation with large carnivores. In Estonia, the respondents mentioned that the implementation of measures is a matter of cost and that they are intended to protect farmers' properties' and not to support the abundance of carnivores.

In Hungary, the experts explained that given the number of jackals in the country, livestock protection is far more relevant than carnivore protection. However, there are a number of governance issues on livestock protection measures that remain to be solved, particularly related to the use and handling of livestock guardian dogs.

In Spain, the interviewees highlighted the need for more support for livestock protection measures and more compensation for damages. Interestingly, one interviewee mentioned that the culture of cohabitation, and knowledge of preventive measures and their application, appears to have been lost in areas where the species have disappeared and are currently returning. In these areas, the respondent claims, it is essential to make great efforts in the transmission of the cohabitation culture.

In Switzerland one respondent put forward that farmers are very much focused on the material loss and emotional pain that carnivores cause and that changing this perception is basically impossible. The other Swiss respondents argued that the full potential of livestock protection has already been exhausted and there is no scope for on-farm measures in favor of carnivores. However, farmers that are also forest owners could potentially contribute to creating attractive (forest-) habitat.

We further asked the interviewees whether farmers have the capability to prevent additional predation on livestock if large carnivore numbers were to increase. Across all countries, the respondents explained that livestock protection requires specific knowledge, financial resources, time and willingness. Some respondents said that farmers are already grappling with issues related to current carnivore population levels and that there is no scope to deal with additional carnivores. One respondent put forward that it is extremely difficult to completely avoid damages if healthy populations of large carnivores occur. Another respondent argued that in areas with traditional and habitual presence of large carnivores, there is generally a good level of knowledge of preventive measures, which can be valuable if carnivore populations increase. In areas of expansion or new presence, this knowledge is often very scarce or non-existent. In either case, the respondent said, it is not only a question of the existence of capacities, but also of the willingness to modify work methods and to implement measures. This willingness is often low in the case that the methods and measures imply an increase in work, temporary dedication, etc. Generally, the NGO representatives were more optimistic about limiting further predation than the other respondents.

3.2.3 Demand

Across the case study countries, the interviewees mostly stated that there is no societal demand for ecosystem services that large carnivores provide to agriculture. One exception was a respondent from Spain who confirmed that society demands and appreciates the ecosystem services provided by large carnivores. In Switzerland a respondent mentioned that there is demand in the forest sector for lynx' and wolves' control of wild ungulate populations, but not in the agricultural sector.

Apart from demand, many respondents asserted that the appreciation of carnivores differs between urban and rural citizens. Rural citizens were stated to be experienced in carnivore matters and approached the topic more rationally. The interviewees explained that due to their closer exposure to carnivores, rural citizens more directly experience the negative and positive aspects of large carnivores than urban citizens. By contrast, they stated that urban citizens approach the issue from an emotional cuteness side and have an idealized conception of large carnivores. Urban citizens were said to enjoy the framing and narrative around large carnivores, especially the 'Yellowstone saga', often with a romantic notion of the wild, while

lacking a sense of the scale of the carnivore problem and being less aware of the benefits that extensive livestock farming provides to nature conservation. Yet, according to the interviewees, the distance to the everyday problems with large carnivores makes it easier for urban citizens to acknowledge the larger context, including possible chances. For example, it was stated that the return of large carnivores can make an otherwise unspectacular landscape attractive, emotional and exciting. Urban residents were stated to be more appreciative of carnivores' ability to regulate ungulates and decrease the risk of zoonosis being spread. A respondent from Estonia summarized that 'urban people don't have sheep, but they take the decisions.' (This being said, one respondent put forward that the urban-rural dichotomy was cooked-up by lobby organizations and does not represent the actual society).

We further asked who in the study countries is responsible for the control of wild ungulates, wild boars and meso-predators. In Romania, Estonia, Hungary, and Switzerland, hunting is managed and implemented by government or sub-national authorities, hunting associations and private hunters. In Estonia there are regions where the hunting limit for feral pigs cannot be met which causes major problems for farmers. Hungary is a special case given that jackals are a huntable species. A respondent mentioned that controlling jackals is in the hunters' best interest because the game population is expected to decrease as jackals increase. In Switzerland the interviewees explained that there are two hunting systems. In the area-based system, hunters pay a lease that is used for measures to improve habitat. If game animals damage crops, the hunters have to pay farmers a share of the compensation. In the license-based system, the financial aspect is less important but the expectations by the local society on hunters' success in managing red deer are enormous. It was further mentioned that game management through hunters is aligned to anthropocentric needs, e.g. keeping damage to crops and forestry low, avoiding road accidents, mitigating pests, sustaining hunting per se as a legitimate cultural good which necessitates adequate stocks of wildlife. Large carnivores obviously do not have these goals in mind and thus cannot be seen as substitutes for hunters. In Spain, respondents explained that the control of ungulates and meso-predators is not part of any officially coordinated program. In the case of wild ungulates, there are local initiatives, hunting associations and protected areas, driven by public administrations that organize the hunt. However, hunting activities are generally not designed to control wildlife populations in order to prevent damages. In urban environments or areas excluded from hunting activities, control activities by regional or municipal authorities exist, especially for wild boar. However, according to one respondent's perception, neither the hunting activities nor the controls developed by the administrations have a relevant effect on the control of the populations of these species. Another respondent asserted that it is nearly impossible to reduce at large scales the populations of wild ungulates without the support of large carnivores.

3.2.4 Legitimation

We asked the interviewees to what extent farmers can ask for lethal control of a large carnivore. In Romania, lethal control of large carnivores is strictly regulated. Farmers who are experiencing severe, repeated economic losses or are imminently threatened by the presence of large carnivores, can contact the authorities. The authorities will take decisions subject to intervention and prevention quotas on culling. In Estonia a farmer can control large carnivores as generally regulated, when the farmer is also a hunter. In Hungary, any legal means other than poisoning can be used to control jackals. According to an interviewee, farmers can report on damage by jackals and ask for lethal control of jackals to protect the livestock. Alternatively, hunters can themselves request permission for lethal control of jackals, or in a shooting event, the master hunter under certain conditions can give permission to shoot jackals.

In Spain, one respondent stated that any farmer can ask for lethal control of a carnivore if the conditions required by the national and European regulations are met. Another respondent explained that the brown bear and the Iberian lynx are protected species that cannot be subject to any lethal control. Wolves were subject to lethal control until recently, by means of hunting activity or by means of controls carried out by regional administrations depending on each territory. According to the respondent, often these controls were carried out as a consequence of complaints from livestock farmers after episodes of attacks. However, wolves

were recently listed under a special protection regime, which grants a homogeneous degree of protection throughout the national territory and prevents its hunting exploitation. As the interviewees explained, this regulatory change is generating a great debate and controversy between the state and regional governments and the future way of management remains unclear.

In Switzerland, respondents were clear that farmers cannot ask for lethal control of carnivores. The only options farmers have, are to implement protective measures or to use the democratic tools to try to change the law.

Finally, we asked how influential farmers are in terms of having a say on large carnivore policies and management decisions. In Estonia and Romania, respondents said that farmers have only moderate influence on carnivore policies and in Hungary, Spain and Switzerland respondents stated that farmers have high influence. In Hungary, farmers have not yet started to politically influence decisions regarding jackals, but as the respondents highlighted, it is a huntable species. In Spain, according to the respondents, farmers have substantial influence at the local and regional level. Demands on large carnivores are usually associated with complaints or claims about the future of livestock farming, the rural crisis, etc., which amplifies the importance of the political message. However, at the national level, a certain frustration was mentioned that the farmer associations' suggestions on carnivore policies were not being heard by the government. In Switzerland, respondents said that policy making is always backed by a dialogue between different stakeholders. Within this dialogue, farmers have substantial convening power, enjoy high esteem and credibility because they are directly affected by large carnivores.

4 Discussion

Our findings reveal that despite the many disservices, there is also a range of ecosystem services that large carnivores can provide to agriculture. These services for the agricultural sector can be categorized as density mediated, behaviorally mediated and cultural services. Our discussion of carnivores' ecosystem services for agriculture adds to a recent body of literature that seeks to develop a more balanced understanding of the effects that carnivores have in our societies as they regain ground in Europe (Rode et al. 2021).

As any study, ours has limitations that need to be kept in mind. Related to carnivores' ecosystem services, it is important to acknowledge that much of the knowledge builds on observations of what happened when large carnivores were removed from their former ranges. As they recolonize their former ranges, new dynamics may unfold that do not necessarily reverse the removal effects (Alston et al. 2019). Our review of ecosystem services provided by large carnivores to agriculture is thus likely to be incomplete and can be expanded in the future as new insights on ecosystem services related to the recolonization process become available. Further, we conducted only three interviews per case study country (in Estonia four): a representative of a farmer's association, an NGO representative and a government representative. We assume that the answers provided by stakeholder representatives express the sentiment of the larger group and go beyond personal opinions. However, a larger sample size would have allowed us to better check for the consistency of our findings. This being said, we would like to reemphasize the difficulties mentioned above that we met in finding interview partners willing to talk to us in times of contentious public debates on large carnivores.

In this research, following Runhaar et al. (2017) and Schoonhoven and Runhaar (2018) we developed a conceptual framework arguing that it takes a combination of motivation, ability, demand, and legitimation for farmers to be willing to shift their production systems toward ecological intensification, in our case ecological intensification with a role for carnivores. While synthesizing the expert interview responses, in general, we found rather dim prospects for such a shift. According to our interviewees' opinions, farmers (apart from a few exceptions) rarely perceive and appreciate benefits for agriculture from the ecosystem services provided by large carnivores. Individual farmers have little ability to take on-farm measures that could impact carnivore populations. Moreover, the interviewees deemed that societal demand for carnivore's ecosystem services is limited albeit differences were reported for urban and rural

citizens. In all study countries, legislations define the set of legitimate measures available to farmers. This includes the question whether farmers can ask for lethal control. An important aspect is that interviewees in all countries said that farmers have leverage in political negotiations on carnivore policies.

We initially hypothesized that motivation, ability, and demand decrease with an increase in agricultural productivity. We could not establish such a general trend in our interview responses. However, there may be some evidence in this direction in the responses on whether farmers perceive benefits from the ecosystem services provided by large carnivores. In Romania, which has a comparatively low agricultural productivity but high carnivore population, farmers were said to benefit from carnivores' ecosystem services, although they do not prize these services. In Estonia, farmers actively substitute for carnivores' regulating services by contracting with hunters in regions with thresholds on carnivore numbers. In Hungary and Spain, the responses indicate that farmers may, to a certain extent, acknowledge carnivores' regulation of wildlife that prevents disease spill-overs to livestock. However, in Switzerland where the agricultural productivity is highest among the study countries, there was no mention of any perceived benefits. We thus mostly observed nuances of unappreciation of large carnivores and their ecosystem services for agriculture.

Our findings are in line with those of Franchini et al. (2021), who in a review of EU-level studies on perceptions toward large carnivores, find consistently negative attitudes among the rural population. They establish that in areas in which carnivores had been eradicated in the past, attitudes were even more negative than in areas where there was human carnivore co-existence.

Our study findings provide little leeway for improving the efficiency and effectiveness of existing policies through an integration of the ecological intensification concept. Nevertheless, our research contributes to expanding the knowledge frontier on ecological intensification as a strategy for human-wildlife coexistence. We argue that more research on benefits provided by large carnivores' to agriculture is needed to complement and move beyond discussions focusing only on decreasing negative interactions (Frank 2016). However, given our findings, a focus on win-win solutions such as ecological intensification with large carnivores may not be realistic. Accepting that trade-offs will always prevail in this context, perhaps a focus on good practices based on an understanding of ecosystem services and disservices may be more promising (Hovardas and Marsden 2022).

5 Policy recommendations

Based on our findings, we propose the following:

1. There is little scope to improve the efficiency and effectiveness of existing carnivore policies through an integration of the ecological intensification concept. However, more research is needed on strategies that can complement and move beyond discussions focusing only on decreasing negative carnivore-livestock interactions.
2. Awareness on carnivores' ecosystem services and disservices could be increased in society at large. The ambition should be to avoid polarization in one or the other direction. Given that large carnivores are regaining ground, an increased awareness of services and disservices can lay the ground for a broad, open-minded discussion on policy options and good practices for carnivore-human co-existence.

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