STUDY *Provisional version*

Requested by the AGRI committee

Research for AGRI Committee - The revival of wolves and other large predators and its impact on farmers and their livelihood in rural regions of Europe

Policy Department for Agriculture and Rural Development
Directorate-General for Internal Policies
PE 617.498 - August 2018

EN

Research for AGRI Committee - The revival of wolves and other large predators and its impact on farmers and their livelihood in rural regions of Europe

Abstract

This study surveys the current status of large carnivores in Europe and assesses their impact on livestock from the available data on compensation payments and from field research. Recommendations on livestock protection measures are provided, as well on the integration of these into locally adapted holistic management systems.

This document was requested by the European Parliament's Committee on Agriculture and Rural Development.

AUTHOR(S)

John LINNELL, Benjamin CRETOIS - Norwegian Institute for Nature Research

Research managers: Marcus BREUER, François NÈGRE
Project and publication assistance: Catherine MORVAN
Policy Department for Structural and Cohesion Policies, European Parliament

LINGUISTIC VERSIONS

Original: EN

ABOUT THE PUBLISHER

To contact the Policy Department or to subscribe to updates on our work for the AGRI Committee please write to: Poldep-cohesion@ep.europa.eu

Manuscript completed in August 2018

Further information on research for AGRI by the Policy Department is available at:
https://research4committees.blog/agri/
Follow us on Twitter: @PolicyAGRI

Please use the following reference to cite this study:
Linnell, J. D. C. & Cretois, B. 2018, Research for AGRI Committee – The revival of wolves and other large predators and its impact on farmers and their livelihood in rural regions of Europe, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels
Please use the following reference for in-text citations:
Linnell and Cretois (2017)

DISCLAIMER

CONTENTS

LIST OF ABBREVIATIONS

CAP	Common Agricultural Policy
CoE	Council of Europe
EAFRD	European Agricultural Fund for Rural Development
EU	European Union
IUCN	International Union for Conservation of Nature
LCIE	Large Carnivore Initiative for Europe – a Specialist Group of the IUCN's Species Survival Commission
NUTS	Nomenclature of Territorial Units for Statistics. These are spatial units used by the EU for administrative purposes. They exist in three hierarchial levels, 1, 2 and 3. There are 1276 units at the NUTS 2 level which we have used in this report.

LIST OF FIGURES

LIST OF MAPS

LIST OF TABLES

1. EXECUTIVE SUMMARY

1.1. Background

The conflict between large carnivores and humans goes back to the origins of domestication, as does the ingenuity of livestock herders in developing ways to protect their livestock. In the last few decades populations of large carnivores like wolves, brown bears, Eurasian lynx and wolverines, have responded to improving habitat conditions and supportive legislation. They have returned to many parts of Europe from where they have been absent for decades / centuries and consolidated their presence in areas where they had declined. However, this recovery has also generated many conflicts with agricultural and rural stakeholders which involve both the direct impact that large carnivores have on livestock through depredation, and a wider range of social conflicts that centre on the challenges that rural communities face in the 21st century where large carnivores become potent symbols.

1.2. Aim

The aims of this report are to:

- Summarise the current status of large carnivore populations in Europe.
- Summarise the impacts that large carnivores are having on livestock production.
- Place this into context against the ongoing trends within livestock production.
- Outline the legal framework that governs large carnivore conservation.
- Explore the potential of different interventions to mitigate the impacts of large carnivores on livestock production.

1.3. Key findings

Based on data from all European countries summarised for the period 2012-2016 there are an estimated 1,000-1,250 wolverines, 8,000 – 9,000 Eurasian lynx, 15,000- 16,000 brown bears and 17,000 wolves present in continental Europe (excluding Russia and Belarus). These are however fragmented into 32 populations (9 for wolves, 10 for bears, 11 for lynx and 2 for wolverines) which vary widely in size from some tens of individuals (and accordingly listed as Critically Endangered) to many thousands (and listed as Least Concerned). Individuals of at least one large carnivore species have been registered in all European countries, except for Luxemburg, during the last 6 years. All carnivore populations overlap with at least one, and up to five, EU countries.

Large carnivore management is governed by two pan-European legal instruments, the Bern Convention (CoE) and the Habitats Directive (EU). These instruments impose certain requirements for the desired level of conservation ambition (i.e. Favourable Conservation Status) for all listed species, although there are differences (depending on which annex / appendix a species is listed under) between species and countries with respect to the circumstances in which animals can be killed. With respect to agricultural interests these restrictions generally require that alternative methods of addressing conflicts have been tried first and that any killing should have no effect on the size of the population. These legal instruments do not open for blanket exclusion or open culling of large carnivores.

Data on livestock killed by large carnivores (mainly compensation payments) was obtained from 19 EU countries (excluding Austria, Romania, Poland, Bulgaria and Spain from which data could not be obtained, and the island states), plus Switzerland and Norway. Sheep, and to a lesser extent goat, represent the most abundant and most widespread livestock killed by large carnivores, and thus are kept as the main focus of the rest of the report. Semi-domestic reindeer represent a special case in the Nordic countries and are treated in an own section. Horses, cattle and beehives are also depredated, but at much lower numbers. Currently, 50% of all sheep in continental Europe are close (within a NUTS 2 region) to an area where at least one species of large carnivore occurs, but this varies dramatically between countries. Several have 100% overlap between large carnivores and sheep production while others have very little.

During 2012-2016 an annual average of 19,500, 1,200, 400 and 4 sheep were reported killed by wolves, bears, lynx and wolverines, respectively, within the sample of EU countries. Including Norway and Switzerland in the analysis would almost double this total because of the huge numbers of sheep killed in Norway. The numbers of sheep attributed as being killed per large carnivore accordingly varies dramatically. For wolves, Norway and France lose over 30 head per wolf, whereas most countries lose between 1 and 14. For bears, Norway and France also lose most sheep, from 10 to 20 per bear, in contrast to the other EU countries where loses are typically only 1 to 2 head per bear. The picture is even more skewed for lynx, with Norway losing 16 sheep per lynx, in contrast to the EU countries where loses are between 0 and 2 head per lynx. Overall, loses to large carnivores are the equivalent of 0.05% of the over-wintering sheep stock (c. 31 million) in the countries included. The total European sheep population is 86 million.

Semi-domestic reindeer in the Nordic countries represent a special situation. They are extensively herded across 30-40% of the area of Norway, Sweden and Finland in landscapes where wolves, lynx and wolverines are quite dependent on reindeer as prey. Although there is much uncertainty about exact numbers killed, losses are known to be very high compared to other livestock. Somewhere between 35,000 and 50,000 are compensated per year, which is a very significant percentage of the total herd (in the order of 500,000 to 700,000 in total for the 3 countries). Reindeer are also exposed to climatic effects as well as negative effects of over-grazing in some areas. There are few practical means to protect reindeer, and current management strategies depend heavily on using lethal control to regulate carnivore populations and compensation payments to offset economic losses.

In contrast to reindeer, there are several tried and tested approaches available to protect other livestock like sheep, goats and cattle. The very high losses that we see in Norway (and partially France and Switzerland) are the result of husbandry systems where sheep graze freely in forest and mountain habitats without fencing, shepherds or dogs to protect them. The fact that neighbouring Sweden and Finland have per capita losses of sheep that are between one hundredth and one thousandth of that in Norway shows the dramatic effect of simply removing livestock from natural habitats and keeping them on fields or other fenced pastures close to farms. Additional protection can be provided by electrifying fencing and / or adding livestock guarding dogs to the herds. In cases where sheep cannot be fenced there is plenty of experience with the use of systems that use shepherds, livestock guarding dogs and night-time enclosures.

Adopting these protective measures can involve everything from minor to dramatic changes to the livestock husbandry systems, with costs varying accordingly. Funding for protection measures can be obtained in part from EAFRD and LIFE. Experience has shown the need for technical assistance and support in adopting all measures. Although there is much resistance to change among farmers, the alternative approach of relying on the unselective culling of carnivores is not viable, because of legal constraints, controversy, high costs, and low effectivity. However, there will always need to be some degree of selective removal of animals using lethal means even in systems where livestock are well protected because no system is 100% effective.

Compensation payments are widespread. While they help protect farmers against economic loss they neither increase tolerance or stimulate changes in husbandry practices. Although there will always be a need for compensation in the case of catastrophic exceptional events and cases when carnivores appear far from their normal range it is highly recommended that most funds be directed towards either financing protection measures directly or paying for risk of exposure, rather than losses.

The use of protection measures, selective lethal-control and compensation need to be integrated into a coordinated livestock strategy that takes the continued presence of large carnivores into account. This strategy requires integrating diverse agricultural, environmental (large carnivores, high-nature-value-farming), heritage and rural development interests. Neglecting to place livestock protection into a broader context will lead to both practical failure at reducing the direct impacts, and failure to address the broader social conflicts. Because of the controversy around large carnivores it is imperative that policies are formulated in inclusive processes that maximise legitimacy, although it is important to be realistic with respect to expectations. Controversy will always remain around large carnivores and may be unrelated to the actual number of livestock killed. Perhaps the biggest challenge lies in designing institutional arrangements that manage to provide the large scale (i.e. the population approach that often requires international coordination) and cross-sectorial coordination that is needed while maintaining the flexibility to adapt to local social, economic and ecological contexts.

2. INTRODUCTION

2.1. Large carnivores: from historical declines to modern recovery

Conserving large carnivores like wolves (*Canis lupus*), brown bears (*Ursus arctos*), Eurasian lynx (*Lynx lynx*) and wolverines (*Gulo gulo*) in the modern European landscape represents both great opportunities and challenges. On a global basis, many species of large carnivores are declining or threatened. In contrast to many people's expectations much of the modern European landscape offers suitable habitat for the conservation of large carnivores and their prey. This is supported by the large areas which are currently occupied by them at present (Chapron et al. 2014), their expansion in many areas, and models that predict that large areas of suitable habitat remain unoccupied (Milanesi et al. 2017). The experience of recent decades has clearly shown that large carnivores do not need wilderness to survive. Rather, when given protection from unregulated killing they have shown an ability to survive in the matrix of semi-natural and heavily modified forest, mountain and farmland landscapes. This provides grounds for conservation optimism with respect to being able to fulfil the goals of the various pan-European nature conservation instruments (e.g. Bern Convention and Habitats Directive) and represents an area where Europe can demonstrate a wildlife conservation success on its home ground in keeping with the principle of universality (i.e. all countries must do what they can) that is enshrined within the UN's Agenda 2030. However, the presence of large carnivores is also clearly associated with a range of impacts[1] on human economic interests and widespread social conflicts between different stakeholder groups with diverging points of view about how large carnivores, and the wider European countryside, should be managed.

2.2. Challenges associated with recovery

Large carnivore depredation on livestock is an age-old phenomenon that undoubtedly goes back to the first days of livestock domestication. Throughout the millennia humans have developed many approaches to protect their livestock from depredation (Linnell & Lescureux 2015), as well as practicing large scale population control and even extermination programs to reduce their impact (Boitani 1995). The historical combination of this direct persecution of large carnivores along with non-sustainable use of forests and their associated wild prey populations led to dramatic declines in carnivore populations, such that they had been exterminated from large parts of Europe and greatly reduced in population density in other parts by the late 19th and early 20th centuries. The combination of greater legislative protection, reforestation, the recovery of wild herbivore populations, and reduced human impacts on the landscape associated with rural-urban migration, land abandonment and urbanisation during the 20th century have created the conditions necessary for a large-scale recovery of large carnivores across Europe. With this recovery of their populations has come a resumption of their depredation on livestock (Kaczensky 1999; Bautista et al. 2017).

[1] Following recent trends in the study of human-wildlife conflicts we separate between "impacts" which is used to describe the effect of large carnivores on livestock and property and which can be measured in economic terms and "conflicts" which is used to refer to the disagreements between stakeholders over the way large carnivores and their impacts should be managed (see Redpath et al. 2013).

2.3. Understanding the complexity of conflicts

A great deal of social science and natural science research has been directed at the conflicts surrounding large carnivores in Europe. As well as the direct psychological, economic and practical impact of livestock being killed it is important to consider the wider social, cultural and political context within which these impacts occur (e.g. Bisi et al. 2007; Hiedanpää 2013; Liukkonen et al. 2009; Luchtrath & Schraml 2015; Skogen et al. 2008, 2017). These typically consist of conflicts between different stakeholder groups about how large carnivores, livestock, and rural areas should be managed. The impacts of large carnivores, especially wolves, and the debates about their conservation and management have become very heated and political in several European regions. Although these conflicts often involve many aspects in addition to depredation on livestock, the killing of livestock is often presented as a key component where the impacts are very visceral and visible. Accordingly, there is also a great deal of controversy concerning the extent of the problem and the potential of different measures to reduce the impacts and associated conflicts. However, research has consistently shown that although the conflicts may appear to be superficially about carnivores killing livestock, they are often far more about deeper social conflicts between rural and urban areas, between modern and traditional values, or between different social and economic classes. There is therefore rarely a clear relationship between the extent of the impact of large carnivores on livestock and the level of social conflict which this generates (Linnell 2013; Jacobsen & Linnell 2016; Skogen 2015). It is therefore imperative that these conflicts surrounding large carnivores and agriculture, and the actions that are needed to mitigate them, be viewed within their social, cultural, economic and political context. As these contexts vary dramatically across Europe, so will the nature of the conflicts around large carnivores.

2.4. Aims and scope of the report

This report aims to summarise present knowledge about several key aspects associated with large carnivore depredation on livestock in Europe, including:

1. The size and trends of European large carnivore populations.
2. The extent to which they depredate on livestock, as revealed through compensation payments.
3. The legal basis underpinning large carnivore management.
4. The relative utility of different protection measures to reduce the impacts of large carnivore on livestock.
5. Wider issues related to trends in agricultural and rural-urban migration that are crucial to understand the context of the wider socio-economic conflicts that develop around large carnivores.

The report focuses on all four large carnivores that are regularly involved in livestock depredation, wolves, brown bears, Eurasian lynx and wolverines because they co-occur in many areas such that the total impact of their depredation is additive in many areas. Furthermore, the measures that may be effective at protecting livestock from one species of carnivore may well be useful at protecting against the others. It is therefore logical to cover all species. However, because of the high degree of political and public focus on the wolf, we pay extra attention to this species. The Iberian lynx (*Lynx pardinus*) and golden jackal (*Canis aureus*) are excluded from this analysis. Iberian lynx are rarely associated with livestock depredation and only have a very limited distribution in southern Spain and Portugal. Golden jackals are excluded because there is almost no data on their depredation on livestock. However, they are expanding rapidly on eastern and central Europe (Trouwborst et al. 2015) and are a species that deserves greater research focus to fill our knowledge gaps.

We also focus as much as possible on the entire continent of Europe, including all EU countries, plus Norway, Switzerland and other non-EU countries in the western Balkans where possible. This continental view is necessary for several reasons;

1. Most large carnivore populations are transboundary, and many EU countries are heavily influenced by non-EU neighbours, and vica versa.
2. Interrelated conservation legislation exists within both the EU and Council of Europe, making it difficult to isolate the mutual obligations.
3. There is a great deal of research and experience that can be transferred from non-EU countries to EU countries.

3. DATA AVAILABLE

Kaczensky et al. (2013) and Chapron et al. (2014) presented data on large carnivore numbers and distribution in Europe for the period 2006-2011. This was based on a questionnaire distributed to a network of researchers, wildlife managers and environmentalists working with large carnivores across Europe. The core of the network was made up of members of an IUCN Specialist Group, the Large Carnivore Initiative for Europe (www.lcie.org), but for this survey we involved a much wider range of experts. The survey also collated information on management system, conflict, and compensation payments. This was supplemented by collating peer-reviewed publications and technical reports from many countries.

However, in 2017, we repeated this survey for the period 2012-2016. All the material from this survey has not been finalised yet but are included here where possible. Data on large carnivore numbers and distribution is compiled from research and conservation projects as well as official national monitoring programs where these were considered accurate by in-country experts. This is therefore the best available data. Data on large carnivores was available for all of Europe (excluding Belarus and Russia, and Ukraine outside of the Carpathian Mountains). A full list of data sources and contacts is provided in Annex 1. Because of the timing of this new survey not all new data was available to integrate into our analyses. In general, we used the carnivore-livestock data from the 2012-2016 survey period and the large carnivore numbers and distribution data from the 2006-2011 survey in our tables and calculations. As the final version of the carnivore data became available in the final stages of writing this report we have integrated these results into tables and maps but were not able to redo all calculations. We mention the data sources in all figures and tables. The situation in the two periods has not changed that dramatically in most areas so it will not change the overall picture substantially.

Data on livestock numbers across Europe were mainly obtained from EuroStat (http://ec.europa.eu/eurostat) and supplemented when necessary from the national statistical offices for Czech Republic, Denmark, Estonia, Ireland, Poland, Slovenia, Finland, Sweden, Switzerland and Norway. For presentation purposes we extracted data on the scale of the EU's NUTS2 regions (plus Norwegian counties and Swiss Cantons). Data on livestock numbers were much more fragmented than expected, with quite a lot of missing data for some countries and years, requiring the integration of data from multiple sources. In most cases it appears that numbers usually reflect the breeding population (excluding young calves, lambs, kids etc), but this was not always specified in databases. There may therefore be some slight inconsistencies in the data, but not enough to significantly skew results. To illustrate the overall trends and patterns in sheep farming we accessed data as far back as 1990 and up to 2017. For many countries the period from 1990 to 2017 has been associated with dramatic socio-political changes associated with the post-communist transition in the east and EU expansion. In keeping with our desire to represent a holistic view it is important to frame eventual large carnivore impacts within the wider geo-political and social contexts that are the main drivers of European agricultural policy.

Where possible, our contacts complied national or regional level official statistics on livestock losses and compensation payments. Not all countries pay compensation or keep centralised databases, therefore this information was not available for all countries or regions. For example, Sweden no longer pay compensation for reindeer killed, rather they pay an amount per large carnivore present, which implies that no data on losses are available (Zabel et al. 2014). Data availability was a bigger problem in countries where responsibility for compensation payments are decentralised to various sub-national levels, where they often have very different systems in different areas. For example, this meant that we could not access data from Poland, Spain or Romania or from large parts of Italy. Some publications have presented partial datasets from parts of these countries (Blanco & Cortes 2009; Boitani et al. 2010;

Mertens & Promberger 2001), but nothing in a way that could be integrated into this comparative presentation. Furthermore, compensation data is not public information in some jurisdictions, for example some of the Austrian states. Map 1 provides an overview of the geographic distribution of data.

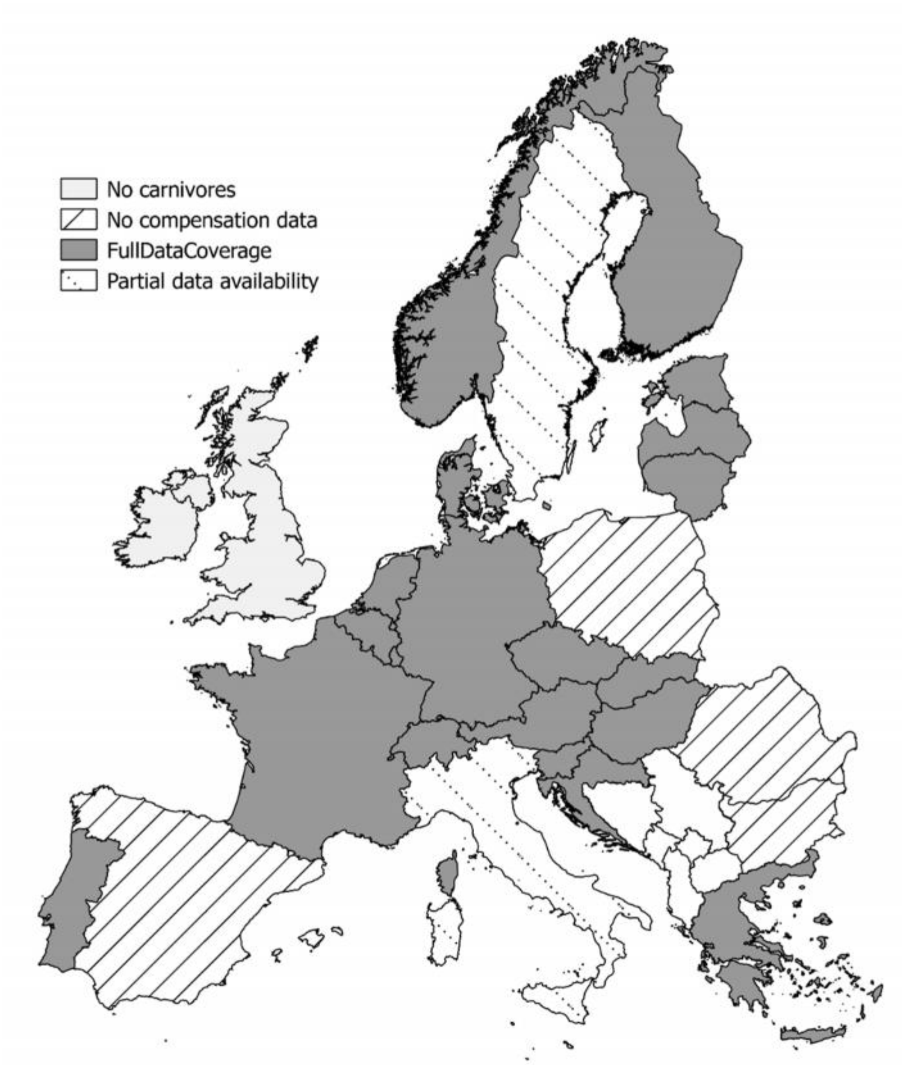
A further issue that must be considered is that different documentation procedures operating in the different countries (Annex 1). Livestock can die or go missing from many causes (starvation, disease, weather, accidents), can be killed by a wide range of predators including red foxes, golden jackals, eagles and dogs (i.e. not just large carnivores) and they are subject to theft. There are even documented cases of herders trying to fake the signs of predator attacks. Predators can also feed on livestock that have died from other causes. All these issues imply that it is far from trivial to assign cause of death to a dead animal, especially if it has been dead for several days and / or only a field autopsy is possible because of logistical issues (i.e. distance to a road for transport to a laboratory).

In most countries there is a requirement that depredation be verified for each case, however, the criteria used to support this documentation and the experience of the observer may vary between regions and countries. The most basic step is to examine all livestock found dead as quickly as possible after death, which requires frequent inspection of herds / pastures. Large carnivore depredation is always associated with physical trauma, so examining a carcass carefully should reveal bites or claw marks. Some species, like lynx, kill very efficiently with one or few bites (usually to the neck or throat), so the signs may be subtle in which case skinning a carcass is almost always necessary. Bite marks accompanied by subcutaneous bruising and bleeding separate depredation from scavenging (where there is no bruising and bleeding). Most carnivores have distinctive prey killing and handling techniques which allows an experienced observer to identify the species of carnivore responsible in the field (Kaczensky & Huber 1994; Levin et al. 2008; Molinari et al. 2000). However, some species leave similar signs. This is especially problematic for the case of wolves, where the risk of confusing between attacks by free-ranging or feral dogs and wolves is rather high. As the desired response to depredation differs among these carnivores (Ciucci & Boitani 1998) it can be critical to separate them. However, some jurisdictions pay for losses due to both wolves and dogs, while others try to separate. Although experienced field workers and technicians may be able to separate between dogs and wolves for some of kills in areas of overlap, visual separation is impossible for many cases. Genetic methods that can identify species on the basis of DNA extracted from a carnivore's saliva left in a bite wound provides a powerful tool for identifying the responsible carnivore objectively (e.g. Caniglia et al. 2013; Sundqvist et al. 2008). For all cases it is crucial that carcasses are rapidly examined by trained inspectors using standardised approaches to ensure fair treatment of herders and to protect against fraud.

Countries like Norway compensate for non-documented cases that are viewed as being likely to have been killed by large carnivores. In this extreme case, less than 10% of all payments are based on a documented kill, with the remainder of the animals simply being lost. The extent of depredation has been highly controversial and hard to quantify because livestock are unsupervised and free-ranging. In response, depredation rates have been studied using radio-telemetry equipment that sends a signal when a sheep or reindeer dies (remains motionless for a set time). This technology allows the rapid discovery and examination of the carcass, increasing the chances of accurately assessing cause of death (Warren & Mysterud 2001; Bjärvall & Franzén 1981; Tveraa et al. 2003; Knarrum et al. 2006). With standard husbandry, this technology may help establish baseline levels of livestock mortality and resolve uncertainty when livestock losses suddenly increase in an area to unknown causes. To date, the methods have only been applied on a large scale in Norway, Sweden, and Finland.

Consequently, the data on losses due to large carnivores should be viewed as an approximation and may be both an overestimate or an underestimate in different settings. Good quality data for countries with sizeable large carnivore populations was available for Germany, the northern part of Italy, Lithuania, Estonia, Finland, France, Czech Republic, Greece, Switzerland, Slovenia, Slovakia, Sweden, Croatia, Norway and Portugal. In addition, there was good data (including the absence of attacks) from countries like Denmark, the Netherlands, Belgium and Luxemburg on the colonisation front of wolves.

Map 1. Geographic distribution of availability of livestock compensation data



4. DISTRIBUTION AND STATUS OF EUROPEAN LARGE CARNIVORE POPULATIONS

KEY FINDINGS

Large carnivores have expanded rapidly across Europe since the mid-20th century. The presence of one or more species has been shown in all continental European countries except for Luxemburg.

There are currently an estimated 17,000 wolves, 15,000 – 16,000 bears, 8,000 – 9,000 Eurasian lynx and 1,000 – 1,250 wolverines in Europe.

Their populations vary widely in size from a few individuals to many thousands of individuals. Accordingly, their conservation status varies widely, with populations having all threat categories from Critically Endangered to Least Concern.

In Europe, wolverines are confined to Norway, Sweden, and Finland, whereas wolves, bears and Eurasian lynx are widespread across the continent (Map 2 a,b,c,d). Populations of all species have shown significant expansion during the last 50+ years (Chapron et al. 2014). For wolves this expansion has been entirely natural without the assistance of translocations or reintroductions. For wolverines there has been some limited assistance with some wolverines being translocated internally within Finland from the alpine tundra areas in the north to the forested areas in the centre of the country. Eurasian lynx have been reintroduced into several areas in central Europe since the 1970's, namely France, Switzerland, Germany, Italy, Slovenia, Croatia, Austria, Czech Republic and Poland (Linnell et al. 2009). There have only been a few bear translocations, namely into the French part of the Pyrenees and into the Italian Alps (Clark et al. 2002; Groff et al. 2018). The general areas of distribution have not changed dramatically between the 2008-2011 survey and the 2012-2016 survey for lynx, bears or wolverines. Wolves have shown greater dynamics with significant expansions in the Alps (including a westward expansion in France and an eastward expansion in Italy) and in the Central European population (with wolves expanding westwards in Germany, consolidating their distribution in western Poland, colonising Denmark and sending dispersing individuals to the Netherlands and Belgium). Austria has also seen the establishment of its first wolf pack. All countries on mainland Europe, with the exception of Luxemburg, have recorded the presence of at least one species of large carnivore during the last 6 years.

The most recent data (Tables 1-4) on the size of European large carnivore populations is available from the period 2012-2016. According to these data there are approximately 1,000-1,250 wolverines, 8,000 – 9,000 Eurasian lynx, 15,000- 16,000 brown bears and 17,000 wolves present in continental Europe (excluding Russia and Belarus). However, these animals are fragmented into a number of discrete populations (2 for wolverines, 11 for Eurasian lynx, 10 for brown bears and 9 for wolves) which have varying degrees of isolation, and which vary enormously in size. Some of these populations only contain a handful of individuals while others contain many thousand individuals. Accordingly, the conservation status (as measured using IUCN Red List criteria http://www.iucnredlist.org/) of these populations varies widely from Critically Endangered (7 populations) to Endangered (5 populations), Vulnerable (7 populations), Near Threatened (4 populations) and Least Concerned (9 populations).

One key characteristic of their distribution in Europe is that almost all populations are transboundary, covering from 2 to 11 countries (only 4 of the 32 populations occur within a single country's borders). The issue of transboundary cooperation in large carnivore management has been highlighted by both the European Commission and the Council of Europe for more than a decade (Linnell et al. 2008).

Map 2. Geographic distribution of (A) wolves, (B) brown bears, (C) Eurasian lynx, and (D) wolverines in Europe, 2012,2016. The maps show areas of permanent presence in dark blue, and of irregular presence in light blue

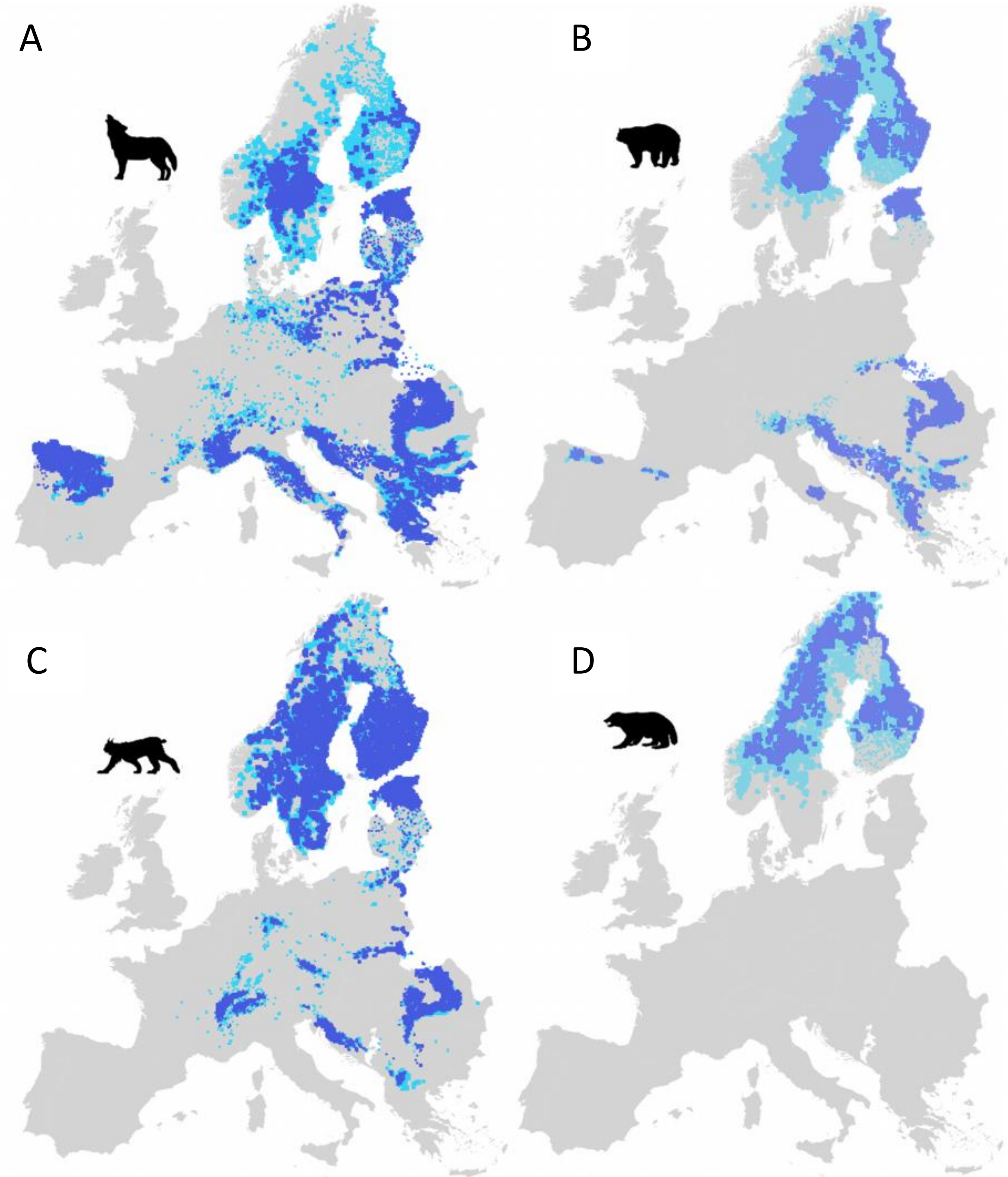


Table 1. The most recent population estimates for wolves in Europe. Data has been estimated from a range of sources. 2008-2011 data is drawn from Kaczensky et al. 2013. 2012-2106 data is from the latest IUCN regional red list assessments. Data are presented on the level of the population

Population	Countries	Last estimate (2008-2011)	Most recent estimate (2012-2016)	Trend	IUCN Red List Assessment1
Iberian	Spain, Portugal	2200-2500[3]	2500	Increasing	Near Threatened
Western – Central Alps	Italy, France, Switzerland	280	420-550	Increasing	Vulnerable
Italian peninsula	Italy	600-800	1100-2400	Slightly increasing	Near Threatened
Dinaric – Balkan	Slovenia, Croatia, Bosnia & Herzegovina, Montenegro, Albania, FYROM, Macedonia, Kosovo*, Greece, Serbia, Bulgaria	c.3900	c.4000	Unknown	Least Concern
Carpathian	Czech Republic, Slovakia, Poland, Ukraine, Hungary, Romania, Serbia	3000	3460-3840	Stable	Least Concern
Baltic	Estonia, Latvia, Lithuania, Poland	870-1400	1713–2240	Stable	Least Concern
Karelian	Finland	150-165	c.200	Stable / increasing	Near Threatened
Scandinavian	Norway, Sweden	260-330	c.430	Increasing	Vulnerable
Central European	Germany, Poland, Denmark	36 packs + 5 pairs	780-1030	Increasing	Vulnerable
Europe[2]			**c.17,000**	**Increasing**	**Least Concern**
EU			**13,000–14,000**	**Increasing**	**Least Concern**

1. IUCN Red List criteria in decreasing order of threat: Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern
2. Europe: Numbers include all countries of continental Europe, excluding Russia and Belarus and all Ukraine apart from the Carpathians. Although the numbers from these countries are not included in the assessment, the degree of connectivity with these areas has been accounted for when relevant.
3. There was no data available for Spain for the period 2008-2011 – so the estimate in this column is from 2006.

Table 2. The most recent population estimates for brown bears in Europe. Data has been estimated from a range of sources. 2008-2011 data is drawn from Kaczensky et al. 2013. 2012-2106 data is from the latest IUCN regional red list assessments. Data are presented on the level of the population

Population	Countries	Last estimate (2008-2011)	Most recent estimate (2012-2016)	Trend	IUCN Red List Assessment1
Alpine	Italy, Switzerland, Austria, Slovenia	45-50	49-69	Stable / slightly increasing	Critically Endangered
Central Apennine	Italy	37-52	45-69	Stable	Critically Endangered
Eastern Balkans	Bulgaria, Greece, Serbia	600	468-665	Stable	Vulnerable
Baltic	Estonia, Latvia	710	700	Stable	Least Concern
Cantabrian	Spain	195-210	321–335	Stable / slightly increasing	Endangered
Carpathian	Slovakia, Poland, Ukraine, Romania, Serbia	7200	7630	Stable	Least Concern
Dinaric Pindos	Slovenia, Croatia, Bosnia & Herzegovina, Serbia, FYROM, Montenegro, Albania, Kosovo*, Greece	3700	3940	Stable to increasing	Vulnerable
Finnish – Karelian	Finland, Norway	1700	1660	Stable	Least concern
Pyrenean	France, Spain, Andorra	22-27	30	Stable	Critically Endangered
Scandinavian	Norway, Sweden	3400	2825	Decreasing	Near Threatened
Europe2			**17,000 – 18,000**	**Stable**	**Least Concern**
EU			**15,000 – 16,000**	**Stable / slight decrease**	**Near Threatened**

1. IUCN Red List criteria in decreasing order of threat: Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern
2. Europe: Numbers include all countries of continental Europe, excluding Russia and Belarus and all Ukraine apart from the Carpathians. Although the numbers from these countries are not included in the assessment, the degree of connectivity with these areas has been accounted for when relevant.

Table 3. The most recent population estimates for Eurasian lynx in Europe. Data has been estimated from a range of sources. 2008-2011 data is drawn from Kaczensky et al. 2013. 2012-2106 data is from the latest IUCN regional red list assessments. Data are presented on the level of the population

Population	Countries	Last estimate (2008-2011)	Most recent estimate (2012-2016)	Trend	IUCN Red List Assessment[1]
Jura	Switzerland, France	>100	140	Slowly increasing	Endangered
Vosges Palatinian	Germany, France	19	1 – 3	Decline	Critically Endangered
Alpine	France, Switzerland, Germany, Italy, Austria	130	163	Slowly increasing	Endangered
Bohemian-Bavarian-Austrian	Germany, Czech Republic, Austria	50	60-80	Stable	Critically Endangered
Dinaric	Slovenia, Croatia, Bosnia & Herzegovina	120-130	130	Stable / decline	Endangered
Carpathian	Czech Republic, Slovakia, Poland, Ukraine, Romania, Serbia	2300-2400	2100-2400	Stable	Least Concern
Scandinavian	Norway, Sweden	1800-2300	1300–1800	Decline	Vulnerable
Karelian	Finland	2430-2610	2500	Stable	Least Concern
Baltic	Estonia, Latvia, Lithuania Poland	1600	1200–1500	Slightly decreasing	Least Concern
Balkan	Albania FYROM Montenegro Kosovo*	40-50	20-39	Stable	Critically Endangered
Harz	Germany		46		Critically Endangered

Europe₂			**8,000 – 9,000**	**Stable**	**Least Concern**
EU			**7,000 – 8,000**	**Stable**	**Near Threatened**

1. IUCN Red List criteria in decreasing order of threat: Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern
2. Europe: Numbers include all countries of continental Europe, excluding Russia and Belarus and all Ukraine apart from the Carpathians. Although the numbers from these countries are not included in the assessment, the degree of connectivity with these areas has been accounted for when relevant.

Table 4. The most recent population estimates for wolverines in Europe. Data has been estimated from a range of sources. 2008-2011 data is drawn from Kaczensky et al. 2013. 2012-2106 data is from the latest IUCN regional red list assessments. Data are presented on the level of the population

Population	Countries	Last estimate (2008-2011)	Most recent estimate (2012-2016)	Trend	IUCN Red List Assessment[1]
Scandinavia	Norway, Sweden	1065	800-1000	Fluctuating, recently decreasing	Vulnerable
Karelian	Finland	165-175	200-250	Slowly increasing	Endangered
Europe[2]			**1000-1250**	**Stable**	**Near Threatened**
EU			**600-800**	**Stable**	**Near Threatened**

1. IUCN Red List criteria in decreasing order of threat: Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern
2. Europe: Numbers from Norway, Sweden and Finland, excluding Russia.

5. TYPES OF LIVESTOCK INFLUENCED BY LARGE CARNIVORE DEPREDATION

KEY FINDINGS

Large carnivores have expanded rapidly across Europe since the mid-20th century. The presence of one or more species has been shown in all continental European countries except for Luxemburg.

There are currently an estimated 17,000 wolves, 15,000 – 16,000 bears, 8,000 – 9,000 Eurasian lynx and 1,000 – 1,250 wolverines in Europe.

Their populations vary widely in size from a few individuals to many thousands of individuals. Accordingly, their conservation status varies widely, with populations having all threat categories from Critically Endangered to Least Concern.

Depredation occurs everywhere that domestic animals and carnivores occur together. However, the extent of depredation and the species involved vary widely. The most basic factor leading to vulnerability is the size ratio between large carnivore and livestock. Small livestock species / breeds (*e.g.* sheep and goats) are vulnerable to being killed by more carnivore species than are large livestock species / breeds (*e.g.* cattle, horses), and juveniles of all species / breeds are vulnerable to more carnivores than are adults. In Europe this implies that cattle and horses are only normally predated by bears and wolves (and it is mainly calves / foals which are killed, rarely adults). Adult sheep and goats are therefore mainly also vulnerable to wolves and bears, with lynx and wolverines most often killing lambs. Reindeer of all ages are vulnerable to wolves, lynx and wolverines, with bears mainly taking calves only. Awareness of which carnivore species are present in an area is an important first step in planning mitigation strategies for livestock, where it is also crucial to understand that different life cycles stages of the livestock (i.e. birth, lactating, independent, mature) will have different vulnerabilities. As a general rule, mitigation measures that protect against wolves and bears, will also protect against lynx and wolverines. This implies that the cost of having more than one species of large carnivore will not be additive.

Within the data on compensation that we obtained for this report the vast majority of cases were sheep, with reindeer also common in Norway, Sweden and Finland only (Figure 1; Tables 5-8). For wolves 71% of all cases were sheep, for bears 65% of all cases were sheep, for lynx 45% of all cases were sheep and for wolverines 45% of all cases were sheep. We have therefore focused most of this report on these livestock species, although all the advice and principles on mitigation will also apply to cattle, goats and horses. The special case of depredation on semi-domestic reindeer is treated in section 9.

Bears are associated with some species-specific impacts. They are not infrequently associated with damaging beehives, fruit trees, grass silo and stores of corn and other grain.

Figure 1. The extent to which different types of livestock appear in compensation payments for different European countries, 2012-2016. Data from wolves, bears, lynx and wolverines are pooled

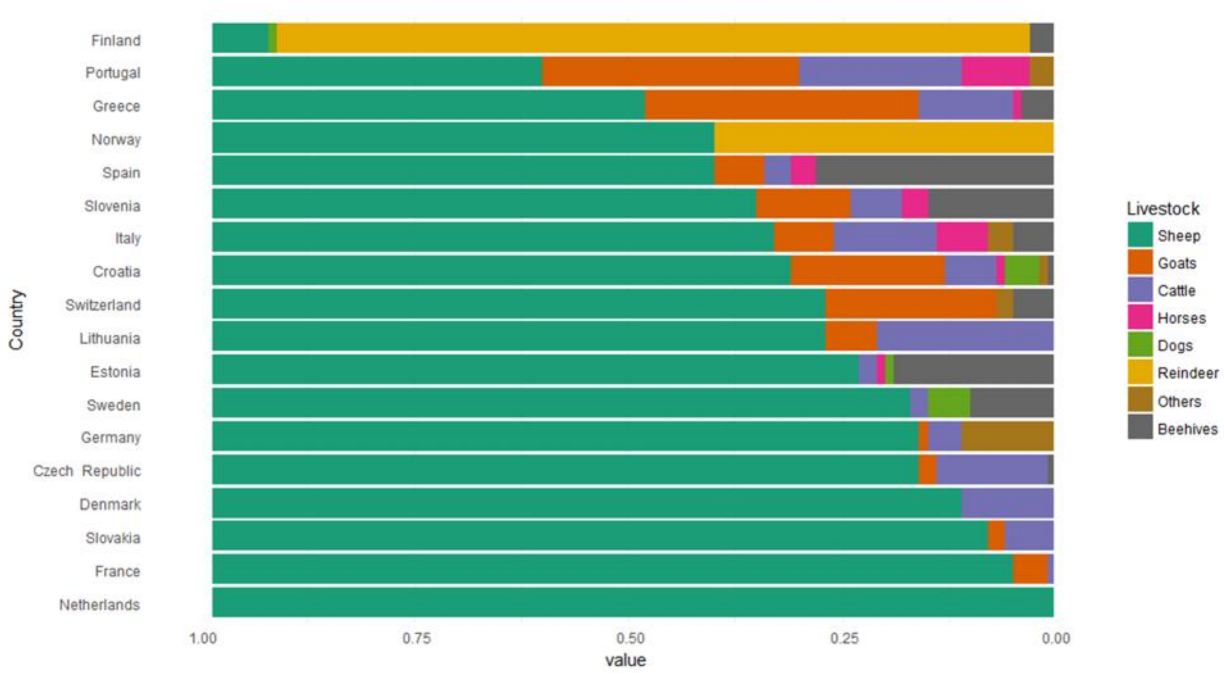


Table 5: Relative representation (%) of different livestock species in compensation payments for different countries attributed to wolves

Country	Sheep	Goats	Cattle	Horses	Dogs	Reindeer	Others
Netherlands	1	-	-	-	-	-	-
Estonia	97	-	2	1	-	-	-
Norway	97	-	-	-	-	3	-
France	95	4	1	-	-	-	-
Czech Republic	95	1	4	-	-	-	-
Sweden	93	-	1	-	6	-	-
Slovakia	92	2	6	-	-	-	-
Denmark	86	-	14	-	-	-	-
Slovenia	84	1	4	2	-	-	-
Germany	83	1	4	-	-	-	11
Lithuania	73	5	2	-	-	-	1
Italy (Apennines)	73	7	13	7	-	-	-
Croatia	69	18	7	1	4	-	1
Greece	55	35	1	1	-	-	-
Portugal	40	3	19	8	-	-	3
Finland	12	1	5	-	-	81	-

Table 6: Relative representation (%) of different livestock species in compensation payments for different countries attributed to bears

Country	Sheep	Goats	Cattle	Horses	Dogs	Reindeer	Others	Beehives
Norway	98	-	-	-	-	2	-	-
France	97	-	-	-	-	-	-	3
Switzerland	76	2	1	-	-	-	7	14
Slovenia	7	-	2	-	21	-	-	7
Czech Republic	67	-	-	-	-	-	-	33
Spain	62	6	3	2	-	-	-	27
Finland	52	-	1	-	1	-	-	46
Sweden	31	1	1	-	1	-	-	66
Greece	25	5	25	2	-	-	-	43
Italy - Alps	2	-	2	3	-	-	25	5
Estonia	3	-	1	-	-	-	-	96
Croatia	3	-	-	-	1	-	33	62

Table 7: Relative representation (%) of different livestock species in compensation payments for different countries attributed to Eurasian lynx

Country	Sheeps	Goats	Cattle	Horses	Dogs	Reindeer		Others
France	1	-	-	-	-	-		-
Sweden	99	1	-	-	-	-		-
Switzerland	61	29	-	-	-	-		1
Czech Republic	61	-	39	-	-	-		-
Norway	46	-	-	-	-	54		-
Germany	39	5	-	-	5	-		51
Slovenia	38	-	-	-	-	-		63
Finland	5	-	-	-	-	94		-

Table 8: Relative representation (%) of different livestock species in compensation payments for different countries attributed to wolverines

Country	Sheep	Goats	Cattle	Horses	Dogs	Reindeer	Others
Norway	54	-	-	-	-	46	-
Finland	-	-	-	-	-	1	-

5. SHEEP PRODUCTION IN EUROPE

KEY FINDINGS

Sheep production has been declining in Europe for decades. The declines have been greatest in western Europe in the older EU members. There have been some increases in the newer EU members, but these have not offset the overall decline.

There are no obvious links between large carnivore presence and these declines.

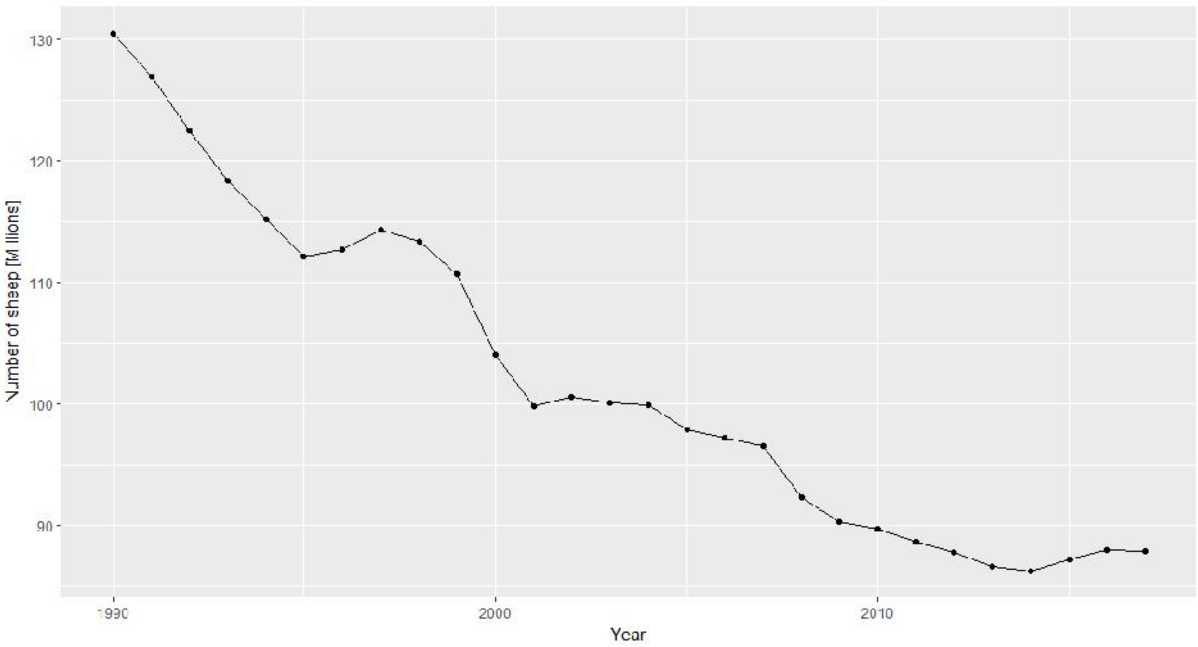
Overall the numbers of sheep in Europe have declined from 130 million to 86 million between 1990 and 2017 (Figure 2). Sheep numbers are therefore currently at around the same level as cattle numbers (beef and dairy) and much less than numbers of pigs (Table 9). However, this decline has not been the same in all countries, and there is a great deal of variation in sheep density across Europe (Map 2). Several countries have seen dramatic declines in numbers of sheep, while others have seen large increases Figure 3). Sheep numbers have generally declined in long-term EU members like Belgium, Germany, France, Italy, Netherlands, United Kingdom, Ireland, Greece, Spain and Portugal. Austria and Denmark represent exceptions as sheep numbers have slightly increased. More recent EU members like Cyprus, Sweden and Finland have also had increasing trends following EU entry. Many of the countries from eastern Europe witnessed major declines in the early years of the post-communist transition. In countries like Poland and Bulgaria this negative trend was not reversed, however in countries like Latvia, Estonia, Slovakia, Czech Republic and Romania this initial decline was partially reversed in recent years, especially following EU accession. EU membership also saw a rise in sheep numbers in countries like Lithuania, Slovenia and Croatia which had never had significant numbers of sheep. Non-EU countries have had variable trends, with numbers being more or less stable in Norway, but declining in Switzerland.

The main driver of change appears to be linked major geo-political changes and EU agricultural policy. None of these trends can be readily linked to large carnivores because of the timing (declines often began before large carnivores returned) and the spatial patterns (declines have occurred in areas with no large carnivores or in areas where carnivores have been a constant presence). Overall it would appear that sheep farming is driven by changes in how subsidy is allocated between countries. It appears that sheep farming has generally declined in the longer-term EU members and has increased in the newer members, indicating that it has been used as a rural development tool in marginal areas and in new members to ease the impacts of transition.

Table 9. Relative numbers of livestock of different species in European countries (in millions of head)

Countries	Cattle	Pigs	Sheep	Goats
Belgium	2.5	6.18	0.08	na
Bulgaria	0.57	0.62	1.36	0.24
Czech Republic	1.34	1.48	0.22	0.03
Denmark	1.55	12.28	0.15	na
Germany	12.47	27.38	1.57	0.14
Estonia	0.25	0.27	0.1	na
Ireland	6.61	1.53	3.44	0.01
Greece	0.55	0.74	8.74	3.89
Spain	6.26	29.23	15.96	3.09
France	19	12.79	7.16	1.2
Croatia	0.46	1.16	0.62	0.08
Italy	6.31	8.48	7.28	1.03
Cyprus	0.06	0.35	na	na
Latvia	0.41	0.34	0.11	0.01
Lithuania	0.69	0.66	0.16	0.01
Luxembourg	0.2	0.1	na	na
Hungary	0.84	2.89	1.16	0.08
Malta	0.01	0.04	0.01	0
Netherlands	4.29	11.88	1.04	0.5
Austria	1.95	2.79	0.38	0.08
Poland	5.97	11.11	0.24	0.04
Portugal	1.64	2.15	2.07	0.35
Romania	2.05	4.71	9.88	1.48
Slovenia	0.49	0.27	0.12	0.04
Slovakia	0.45	0.59	0.37	0.04
Finland	0.89	1.2	0.16	0.01
Sweden	1.44	1.47	0.58	na
United Kingdom	9.81	4.54	23.82	0.1
Switzerland	1.56	1.44	0.34	0.08
Norway	0.85	1.7	1.1	0.3
Total	**91.49**	**150.35**	**86.92**	**13.63**

Figure 2. Trends in sheep numbers in Europe 1990-2017



Map 3. Sheep density in Europe on the level of NUTS2 (+ Swiss cantons and Norwegian counties)

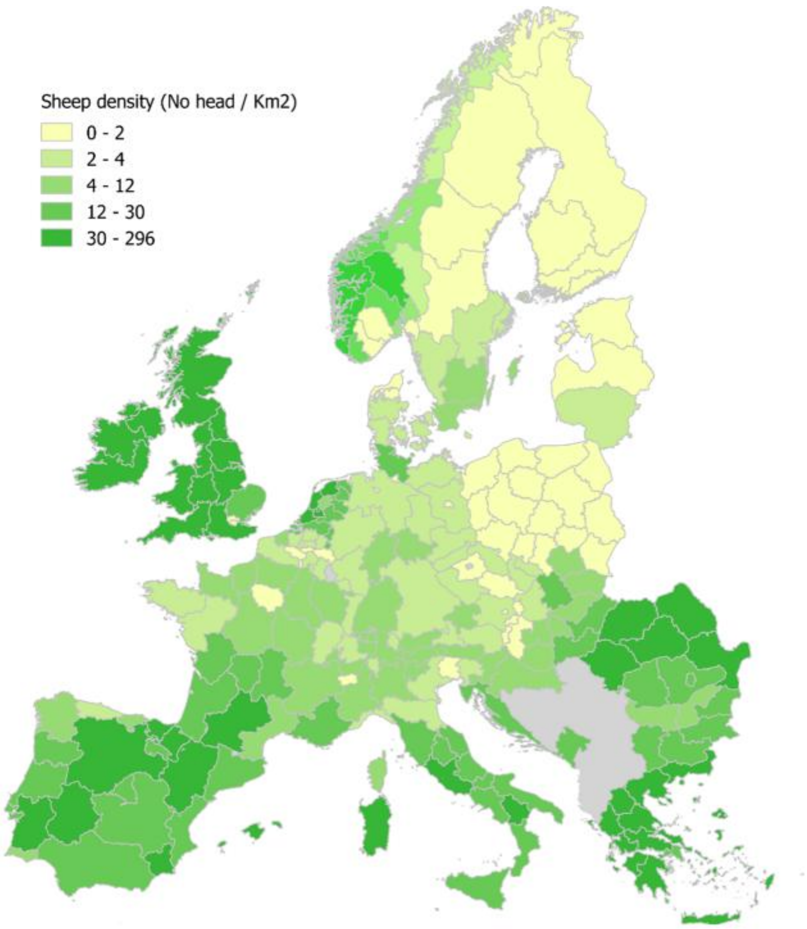
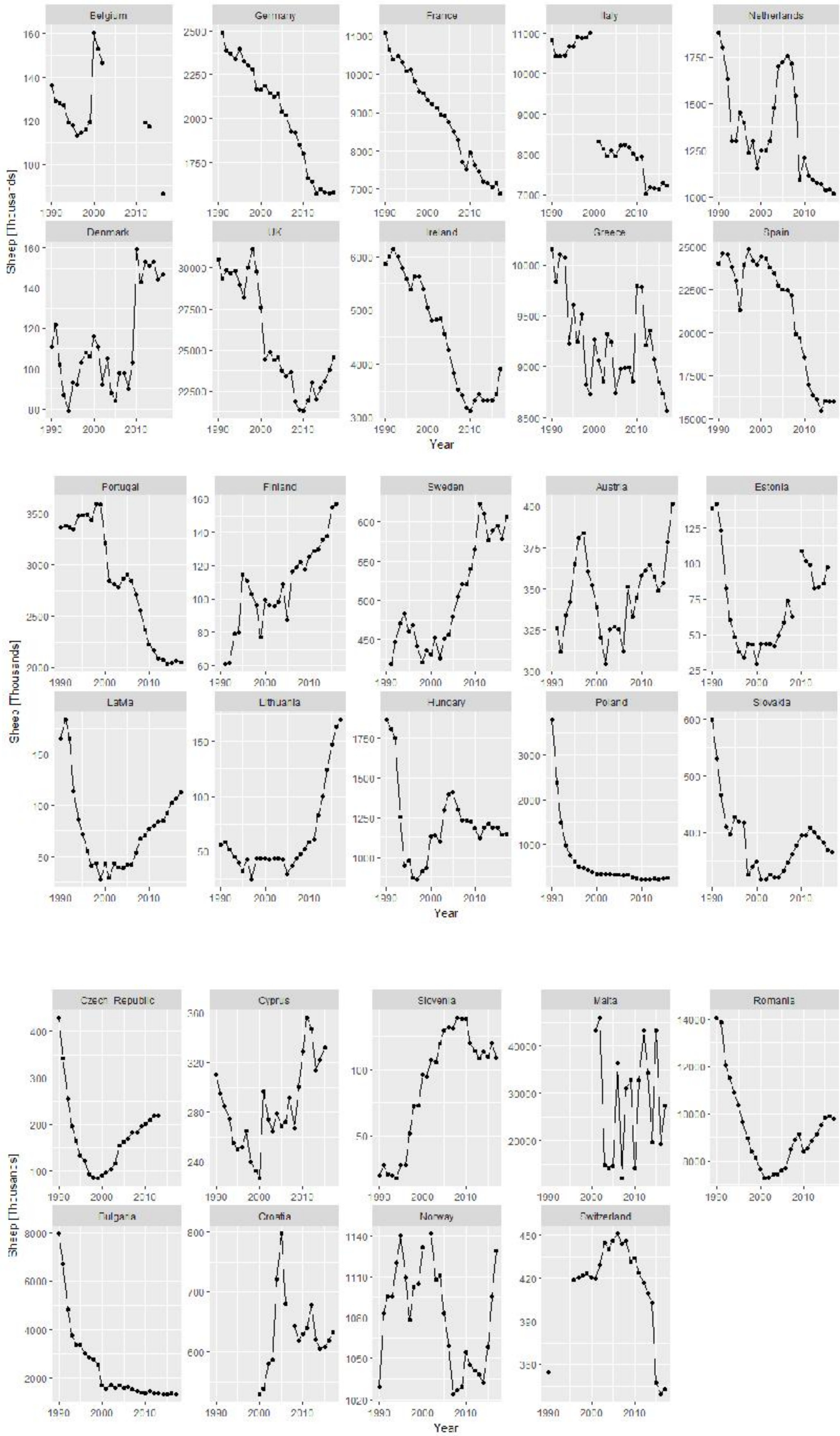


Figure 3. Trends in sheep numbers in the European Union, plus Switzerland and Norway



6. OVERLAP BETWEEN LARGE CARNIVORES AND SHEEP PRODUCTION

KEY FINDINGS
On a broad scale there is a lot of overlap between large carnivores and sheep in Europe, however the overlap varies massively between countries. This opens for the regional targeting of areas for investment in livestock protection.

Of the 86 million sheep in Europe (EU28, plus Norway and Switzerland) about 60 million are present on the continental mainland where large carnivores exist (58.5 million in EU, i.e. excluding Norway and Switzerland). To illustrate the broad scale spatial overlap between large carnivores and sheep production we overlaid the 2008 – 2011 maps of permanent large carnivore distribution with maps of sheep numbers on the NUTS 2 level. If at least 5% of a NUTS 2 region overlapped with carnivore presence we included the whole region as "exposed". This does not imply that all these animals have regular exposure to resident large carnivores because many of the NUTS 2 regions are very large. We have also not taken into account habitat barriers like open water, highways, urban areas and transportation infrastructure which may block carnivore movements. However, it does imply that many sheep live in proximity to carnivore populations so that they may become exposed in the future if carnivore populations expand or to the occasional presence of dispersing juvenile carnivores.

Overall, approximately 50% of the sheep in continental Europe are in a NUTS 2 region where 1 or more species of large carnivore occur (Map 4 a,b,c,d). However, the results (Tables 10-13) show that there is enormous variation between countries in the extent to which their national sheep herd is exposed to large carnivores. In some countries like Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovakia, Slovenia, Finland, Sweden and Croatia virtually all of the national sheep herd is within a NUTS 2 region that overlaps with at least 1, and most often 2 or 3, species of large carnivore. The large carnivores have also had stable and long-term presence in these countries. In such areas the presence of large carnivores can only be viewed as part of the normal environment within which sheep production occurs. In contrast other countries such as France, Germany, Czech Republic, Spain, Portugal, Hungary and Norway have only smaller proportions of their national herds exposed to large carnivores. These are also countries where large carnivores have been returning after long absences.

Information like this shows how it is possible to take a detailed local scale look at risk. Such information can be very important when planning how to use various economic and policy tools to minimise and mitigate risk.

Map 4. Overlap between areas of permanent presence of large carnivores and sheep density in Europe, for (A) wolves, (B) brown bears, (C) Eurasian lynx, and (D) wolverines

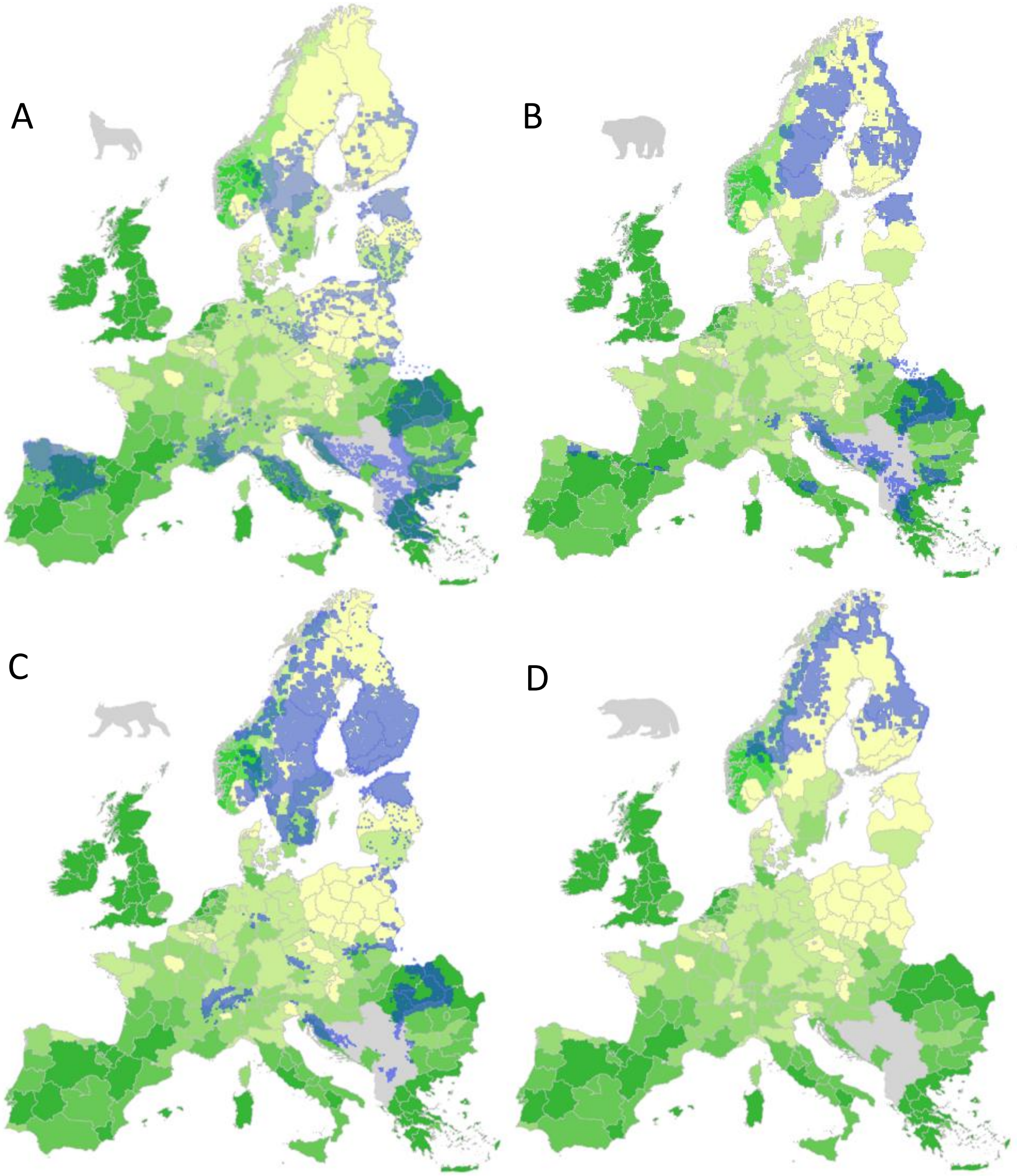


Table 10. Proportion of national sheep herd which overlaps with areas of wolf distribution. Only countries on the continental mainland are included, and only countries where a given carnivore species are present are listed in a specific table. If at least 5% of a NUTS 2 region overlapped with areas of permanent carnivore presence it was included in its entirety. Carnivore distribution data is taken from Chapron et al. 2014, and therefore represents the situation up to 2011

Country	Total number of sheep in country (millions)	Proportion of national herd that overlaps with wolf distribution
Bulgaria	1.36	100
Estonia	0.1	100
Croatia	0.6	100
Latvia	0.11	100
Lithuania	0.16	100
Slovenia	0.1	100
Romania	9.9	100
Slovakia	0.37	87
Poland	0.24	82
Greece	8.7	65
Finland	0.16	64
Sweden	0.58	53
Italy	7.28	37
Switzerland	0.26	37
Portugal	2.1	37
Spain	16	23
France	7.1	17
Germany	1.6	9
Hungary	1.1	8
Norway	1.1	7
Czech Republic	0.22	1
Total	**59.2 million**	**27.7 million (46%)**

Table 11. Proportion of national sheep herd which overlaps with areas of brown bear distribution. Only countries on the continental mainland are included, and only countries where a given carnivore species are present are listed in a specific table. If at least 5% of a NUTS 2 region overlapped with areas of permanent carnivore presence it was included in its entirety. Carnivore distribution data is taken from Chapron et al. 2014, and therefore represents the situation up to 2011

Country	Total number of sheep in country (million)	Proportion of national herd that overlaps with bear distribution
Estonia	0.1	100
Slovenia	0.1	100
Slovakia	0.37	100
Romania	9.9	100
Finland	0.26	88
Bulgaria	1.4	75
Croatia	0.62	61
Greece	8.7	49
Poland	0.24	40
Norway	1.1	31
France	7.1	27
Sweden	0.58	15
Spain	16	4
Italy	7.3	3
Total	**53.7 million**	**19.6 million (36%)**

Table 12. Proportion of national sheep herd which overlaps with areas of Eurasian lynx distribution. Only countries on the continental mainland are included, and only countries where a given carnivore species are present are listed in a specific table. If at least 5% of a NUTS 2 region overlapped with areas of permanent carnivore presence it was included in its entirety. Carnivore distribution data is taken from Chapron et al. 2014, and therefore represents the situation up to 2011

Country	Total number of sheep in country (million)	Proportion of national herd that overlaps with lynx distribution
Estonia	0.1	100
Croatia	0.62	100
Latvia	0.11	100
Lithuania	0.16	100
Slovenia	0.1	100
Sweden	0.58	100
Slovakia	0.37	100
Romania	9.9	100
Switzerland	0.26	95
Finland	0.16	93
Norway	1.1	69
Poland	0.24	63
Czech Republic	0.22	44
France	7.1	7
Total	**21.1 million**	**13.8 million (65%)**

Table 13. Proportion of national sheep herd which overlaps with areas of wolverine distribution. Only countries on the continental mainland are included, and only countries where a given carnivore species are present are listed in a specific table. If at least 5% of a NUTS 2 region overlapped with areas of permanent carnivore presence it was included in its entirety. Carnivore distribution data is taken from Chapron et al. 2014, and therefore represents the situation up to 2011

Country	Total number of sheep in country (million)	Proportion of national herd that overlaps with wolverine distribution
Finland	0.16	64
Norway	1.1	56
Sweden	0.58	15
Total	**1.9 million**	**0.8 million (43%)**

7. LARGE CARNIVORE IMPACT ON SHEEP AND OTHER LIVESTOCK BASED ON COMPENSATION PAYMENTS

KEY FINDINGS

Compensation data was at least partly available from most EU countries, with the exception of Poland, Romania, Spain, Bulgaria, and Austria, in addition to Norway and Switzerland .

For the period 2012-2016 an annual average of 21,000 sheep were compensated as being killed by large carnivores within the EU countries, of which 92% were attributed to wolves.

When included Norway and Switzerland, the total almost doubled to 39,000, but the proportion due to wolves decreased to 56% because of the large numbers of sheep killed by lynx and wolverine in Norway.

France, Portugal, Greece, Croatia and Italy stand out as hot spots for wolf depredation. Between them, these 5 countries represent 75% of all wolf depredations within our EU dataset. The high depredation levels appear to be associated with countries that have either husbandry systems with unprotected free-ranging livestock and / or low densities of wild prey.

Overall depredation losses are equivalent to around 0.05% of the over-wintering sheep stock on mainland Europe.

We were able to obtain compensation data from most European countries (with the exception of Austria, Spain, Bulgaria, Romania, Poland and parts of Italy in the EU) plus Switzerland and Norway (Tables 14 - 17). The island states of Ireland, Cyprus, Malta and the United Kingdom don't have large carnivores – so we refer to the remaining EU countries (i.e. on mainland and with data available as the" EU sample"). The average (2012-2016) annual total numbers of sheep compensated in the EU sample were 19,564 for wolves, 1,215 for bears, 402 for lynx and 4 for wolverines. The figures would be 21,775 for wolves, 3920 for bears, 5,698 for lynx and 7,471 for wolverines when including Norway and Switzerland. The difference between the EU sample and the total is mainly due to the fact that a very large majority of sheep depredation in Europe occurs within Norway (7% for wolves, 54% for bears, 92% for lynx and 99% for wolverines).

The data demonstrate that there are clear differences in the extent to which different carnivores are responsible for livestock depredation. Within the EU sample, wolves are associated with 92% of all cases of compensated sheep depredation, with the other species responsible for 6% (bears), and 2% (lynx). The figures change slightly when including the non-EU countries with wolves responsible for 56% of compensated depredation and the other species for 10% (bears), 14% (lynx) and 19% (wolverines). The difference is again because of the extent to which lynx and wolverines depredate sheep in Norway, which is totally unique in a European context.

There are also clear differences between countries in the extent to which they are exposed to depredation. Figure 4 shows the per capita depredation rate (i.e. the number of livestock killed per large carnivore individual) by wolves, bears and lynx on small stock (sheep + goats). As previously mentioned Norway stands out in a class of its own, which is even more pronounced when the small size of their large carnivore populations are considered. This is because most sheep (with their lambs of the year) are free-grazed in forested and alpine-tundra habitats, with very low levels of supervision. This form of husbandry leads to maximal exposure to large carnivores and minimal protection. While this form of husbandry made sense during the mid-20th century when large carnivores had been virtually exterminated, it has been at the heart of 40 years of conflict once their populations began to recover. Little has been done to change husbandry on a large scale such that the conflict has become chronic. The husbandry form also explains why lynx and wolverines only really kill sheep in significant numbers in Norway (Gervasi et al. 2014; Mattisson et al. 2014; Odden et al. 2014). A striking comparison is that between Norway and Sweden. Per capita depredation rates in Norway and Sweden are 34 vs 0.85 for wolves, 20 vs 0.01 for bears, and 16 vs 0.1 for lynx indicating that Norwegian depredation rates are more than 100 times higher. The key difference is that Swedish sheep are kept behind fences (often electrified) while Norwegian sheep graze freely and unprotected.

The large numbers of sheep killed by wolves in France is also probably due in part to the same situation with many unprotected free-ranging sheep in alpine pastures. Although the massive investment in protection measures has eased losses in areas where wolves have become regular residents, the ongoing expansion of wolves leads to a constant need to modify husbandry in new areas and resulting time lags in mitigation implementation. Greece, Croatia, Italy and Portugal also compensate large numbers of sheep following wolf attacks. These rates are probably due to a range of factors, that also include husbandry, but are also associated with many areas that have low densities of wild ungulates such that wolves have no alternative prey sources. There is also the potential problem that many of the supposed "wolf" kills in the southern countries (not France) may be due to feral or free-ranging dogs which are abundant, and where management authorities may simply pay for dog kills whenever there is doubt about the identity of the depredator (Boitani et al. 2010; Ciucci & Boitani 1999).

What is also striking is the number of countries where depredation rates are very low, for example below 5 small stock per wolf, or below 1 small stock per bear or lynx, in many countries, including some which have substantial large carnivore populations. These examples indicate that the costs of having large carnivores do not need to be high if livestock is kept in appropriate ways.

When considering the number of sheep (c. 31 million) present in the EU sample countries these levels of depredation correspond to the annual killing of 0.06% (wolves), 0.004% (bears), 0.001% (lynx) and an insignificant number (wolverines). These numbers are actually overestimates, because the sheep numbers usually do not include lambs, and a very large proportion of the animals killed by carnivores are lambs. However, it is important to bear in mind that the picture may be rather different locally because individual herds or regions can be exposed to chronically high rates of depredation, or single attacks with very large numbers of animals killed. On the other hand, many producers are not exposed at all (see previous section). In a pan-European overview like this it is not possible to reveal this fine-scale variation.

Table 14. Number of livestock compensated per year (average for 2012-2016) attributed to wolves in Europe

Country	Sheep	Goats	Cattle	Horses	Dogs	Reindeer	Others
France	7511	370	61	7	8	-	6
Greece	3450	2194	606	33	-	-	0
Norway	2211	1	1	-	5	51	-
Portugal	1967	1510	940	407	7	-	125
Croatia	1787	477	170	22	114	-	29
Italy (Apennines)	1739	173	300	156	-	-	-
Estonia	767	3	14	5	5	-	-
Slovenia	548	49	21	12	-	-	-
Lithuania	499	38	141	-	-	-	3
Germany	427	6	21	-	-	-	59
Sweden	374	1	12	2	32	-	-
Slovakia	368	7	25	-	-	-	-
Switzerland	261	4	1	-	-	-	
Latvia	149	5	5	-	2	-	-
Finland	95	-	10	1	41	623	-
Czech Republic	21	-	-	-	-	-	-
Denmark	10	-	1	-	-	-	-
Netherlands	1	-	-	-	-	-	-
Total	**22,185**	**4,837**	**2,329**	**645**	**214**	**674**	**222**
Total EU[1]	**19,713**	**4,833**	**2,327**	**645**	**209**	**623**	**222**

1. Excluding data from Austria, Poland, Spain, Bulgaria and Romania for all livestock species, and for Sweden for reindeer.

Table 15. Number of livestock compensated per year (average for 2012-2016) attributed to brown bears in Europe

Country	Sheep	Goats	Cattle	Beehives	Horses	Dogs	Pigs	Reindeer	Others
Norway	2705	-	-	-	-	-	-	179	-
Slovenia	461	-	11	46	-	137	-	-	-
France - Pyrenees	311	-	-	10	-	-	-	-	-
Greece	150	28	145	256	11	-	-	-	-
Finland	141	-	2	125	1	2	-	647	-
Italy - Alps	57	-	7	138	7	-	-	-	69
Sweden	30	1	1	64	-	1	-	-	-
Spain – Pyrenees	22	2	1	10	1	-	-	-	-
Switzerland	34	-	-	3	-	-	-	-	1
Estonia	6	-	3	187	-	-	-	-	-
Croatia	2	-	-	19	-	-	-	-	10
Czech Republic	1	-	-	1	-	-	-	-	-
Total	**3920**	**31**	**170**	**859**	**20**	**140**		**826**	**80**
Total EU[1]	**1215**	**31**	**170**	**859**	**20**	**140**		**647**	**80**

1. Excluding data from Austria, Spain, Poland, Bulgaria and Romania for all livestock species, and for Sweden for reindeer.

Table 16. Number of livestock compensated per year (average for 2012-2016) attributed to Eurasian lynx in Europe

Country	Sheep	Goats	Cattle	Reindeer	Dogs	Horses	Others
Norway	5296	2	1	6207	-	-	-
Sweden	145	1	1	-	-	-	-
France	102	-	-	-	-	-	-
Finland	32	-	2	678	2	1	3
Estonia	30	-	1	-	-	-	-
Switzerland	19	9	-	-	-	-	3
Czech Republic	16	-	10	-	-	-	-
Germany	5	-	-	-	1	-	6
Slovenia	1	-	-	-	-	-	1
Latvia	2	-	-	-	-	-	-
Slovakia	1	-	<1	-	-	-	-
Lithuania	0	-	-	-	-	-	-
Croatia	0	-	-	-	-	-	-
Total	**5646**	**12**	**14**	**6885**	**3**	**1**	**13**
Total EU[1]	**341**	**6**	**13**	**678**	**3**	**1**	**13**

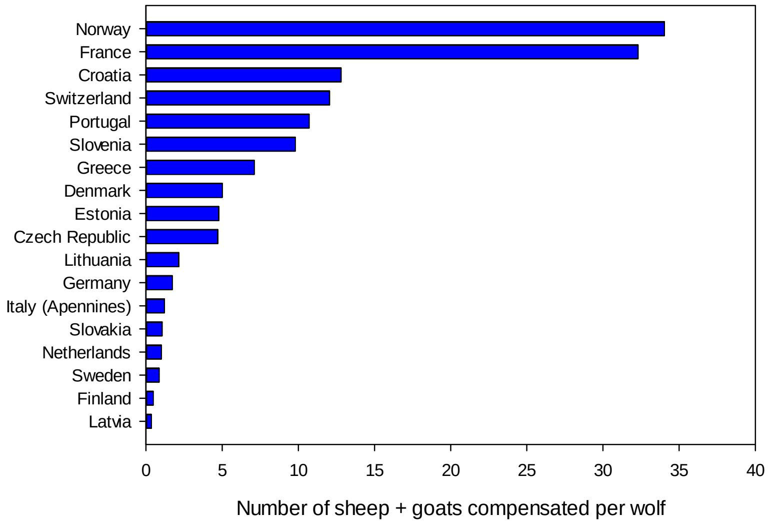
1. Excluding data from Austria, Spain, Poland, Bulgaria and Romania for all livestock species, and for Sweden for reindeer.

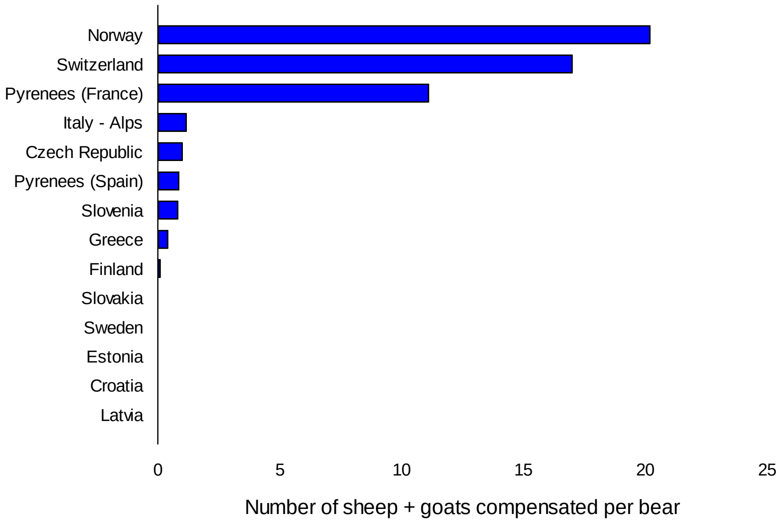
Table 17. Number of livestock compensated per year (average for 2012-2016) attributed to wolverines in Europe

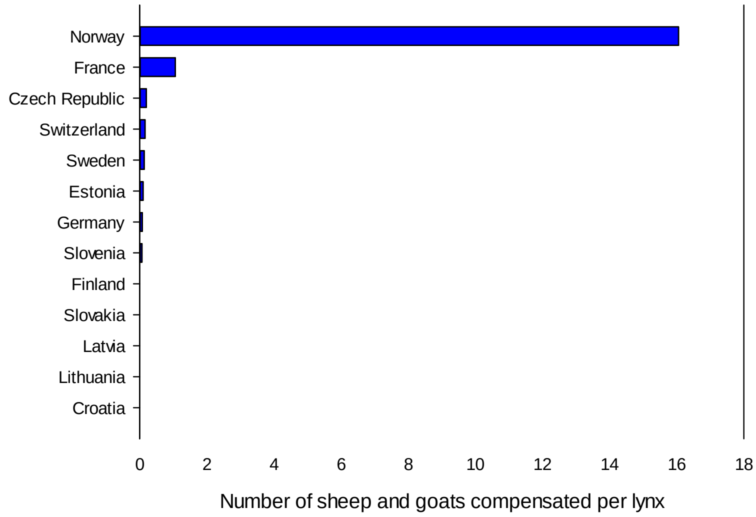
Country	Sheep	Goats	Cattle	Reindeer	Dog	Others
Norway	7467	-	-	6234	-	-
Sweden	2	-	-	-	-	-
Finland	2	-	-	2766	-	2
Total	**7471**			**9000**		**2**
Total EU[1]	**4**			**2766**		**2**

1. Excluding data from Austria, Spain, Poland, Latvia, Bulgaria and Romania for all livestock species, and for Sweden for reindeer.

Figure 4. Per capita depredation. Numbers of sheep and goats compensated per individual of wolf, brown bear or Eurasian lynx







8. THE EFFECT OF LARGE CARNIVORES ON LIVESTOCK PRODUCTION

KEY FINDINGS

In addition to direct mortality there are widespread claims that the presence of large carnivores causes other negative effects on livestock behaviour and condition. However, there is currently no scientific quantification of these secondary effects.

Adopting new protection measures can be challenging for many producers, especially in countries with high labour costs. There are also many other challenges facing livestock producers that must be considered when determining how to implement protection measures.

In the previous section we have summarised the existing data from a range of European countries concerning the direct losses that large carnivores cause to livestock in terms of animals killed or injured to the extent that compensation has been paid. In addition to these direct impacts are many other potential impacts which are reported by livestock producers.

The first concerns animals which are lost and never found and where large carnivores are believed to be responsible. Countries vary dramatically in the way in which compensation for lost animals is administered. Livestock die or vanish from many causes, including accidents, weather, disease, theft, and predation by other species like dogs, foxes, jackals, eagles. There has generally been very little agricultural research conducted into livestock mortality causes. Although many countries veterinary services examine carcasses, the problem concerns those which are not found. The technology to study this objectively has existed for decades as livestock can be radio-collared in the same way as wildlife. This allows animals to be located and examined if a mortality-sensor is activated. However, it has only been widely used in the Nordic countries. An increased focus in veterinary and agricultural research using such approaches would be very helpful in resolving some of the controversy around the extent of livestock losses. A second approach involves studying the predators using radio-telemetry techniques that allow the quantification of their kill rates (how many livestock they kill in a given season). Again, this has been widely used only in Fennoscandia (e.g. Odden et al. 2014) and to a small extent in France (Stahl & Vandel 2001). Although these research approaches are very expensive, they do provide very useful data into both the ecology of depredation and to help quantify its impacts on livestock. They also allow the identification of other causes of mortality which may require veterinary responses. In an era with many emerging zoonotic diseases (that can transfer between wildlife and domestic animals) it is becoming increasingly important to monitor livestock mortality, especially in areas where they graze in areas with a broad interface with wildlife. The overall emergence of zoonotic diseases is inevitably going to lead to questions about the extent to which it is desirable to maintain a broad interface between wild and domestic ungulates.

It is widely claimed by shepherds and livestock breeders that the presence of large carnivores causes stress and influences livestock behaviour and body condition. While such effects are certainly plausible they remain poorly documented. One study has looked at the issue in an indirect manner without finding any support for weight loss (Mabille et al. 2016), but there is a clear need for more research into this topic. Another frequent claim is that high rates of depredation losses reduce the freedom of herders to selectively breed their herds (Heikkinen et al. 2011).

The existence of compensation schemes (for losses) and incentives / support schemes (to help producers modify their husbandry to better protect livestock – see section 11) serve to reduce some of the economic impacts of large carnivores (see section 12). However, the biggest impact is likely to come from the increased demands for labour inputs. In situations where livestock are already fenced on fields or pastures the additional labour demands which are needed to protect livestock from large carnivores are likely to be low after the initial installation of measures like electric fences or livestock guarding dogs. However, in free-ranging systems the extra labour costs associated with shepherds and livestock guarding dogs may be very high indeed as compared to a situation with no large carnivores where much less supervision is required.

The issue of labour costs is especially significant in the small-scale livestock production which is typical of many of the areas where large carnivores occur. This is because low intensity livestock production is already under pressure from a wide range of drivers. In many areas, Europe is witnessing a movement of people away from rural areas with an associated abandonment of marginal farm lands and declines in livestock. The producers who remain active face many economic uncertainties. A range of studies have examined the drivers of change in small scale agriculture and the motivations of farmers / livestock producers to continue or stop (Benayas et al. 2007; Defrancesco et al. 2018; Farinella et al. 2017, Hadjigeorgiou 2011; Hazel & Wood 2008; Kuemmerle et al. 2008; Sendyka & Makovivky 218; van Vliet et al. 2015). Virtually all the drivers listed are external factors, including;

1. Lack of competitiveness in the face of agricultural intensification and market forces (international trade, globalisation of markets).
2. Problems to find markets and low demand for sheep products.
3. Lack of a new generation to take over.
4. Problems to find qualified or experienced shepherds.
5. General hardships of the lifestyle with high labour input and low economic return.
6. Low social status of livestock producers.
7. Challenges of securing access to pastures which are usually not owned by the producers.
8. The availability of more lucrative off-farm employment.
9. The general decline in rural infrastructure services (closure of local schools, police stations, post offices, churches) which are key drivers of rural-urban migration in general.

The CAP has long contained mechanisms to try and support small scale farmers, including livestock producers in marginal areas. But the impact of this has been highly variable. There are a number of studies that have explored the potential of EAFRD funds (http://ec.europa.eu/environment/nature/conservation/species/carnivores/case_studies_sub_rural_development_programmes.htm) and other economic instruments to facilitate the coexistence of livestock production and large carnivores (Marsden et al. 2016). The key issue is that the conflict between large carnivores and agriculture, and the utility of possible mitigating measures, both need to be analysed within the wider frames of both agricultural and rural development policy (Hinojosa et al. 2018). We explore this in greater detail in the final section.

9. THE CASE OF SEMI-DOMESTIC REINDEER IN NORTHERN EUROPE

KEY FINDINGS

Semi-domestic reindeer are herded in Norway, Sweden and Finland.

Although there is much uncertainty about the exact losses there is broad research- based support for the finding that depredation rates from lynx, bears, wolverines and wolves are higher on reindeer than for any other livestock in Europe. In addition, reindeer are vulnerable to climatic effects and side-effects of locally high densities.

There are few practical protection measures, and management currently rests on the strategy of using lethal-control to regulate carnivore populations and the economic compensation for losses.

Semi-domestic reindeer are associated with northern Europe, being grazed in Norway, Sweden and Finland (as well as Russia). The numbers of reindeer are broadly similar in all three countries, with herd size fluctuating around 200.000 (150.000 to 250.000) animals in each country. In Norway and Sweden, reindeer herding is conducted across approximately the northern 40% of the countries, while reindeer herding is conducted across 33% of northern Finland. Reindeer herding is also intrinsically linked to the Sami people (Jernsletten & Klokov 2003). In connection with large carnivores, this type of livestock is associated with a number of specific challenges.

1. Reindeer are exposed to depredation from all four large carnivores, wolves, brown bears, lynx and wolverines. Because wolverines may scavenge on kills made by other species it is not always clear if the presence of multiple predators has an additive impact or not (Andrén et al. 2011).
2. Throughout most of the northern parts of the reindeer herding districts there are very low densities of alternative prey for large carnivores such that the presence of large carnivores is virtually dependent on their access to reindeer as prey (Pedersen et al. 1999). This also implies that most of the range of wolverines in Europe is found within the semi-domestic reindeer herding areas with the exception of areas in the south where wolverines are expanding (e.g. Aronsson & Persson 2017).
3. The fact that large carnivores kill reindeer is well documented in many studies, but there is considerable uncertainty about the numbers. The extensive form of husbandry, and the wide-ranging movements of reindeer makes it very hard for herders to find carcasses to document mortality cases and ascertain the causes. This is especially true during summer when young calves are most vulnerable. Being small they are often totally consumed,a nd remains decompose fast. Many studies have been conducted using radio-collars to study the mortality of reindeer (e.g. Bjärvall et al. 1990; Nieminin & Leppäluoto 1988; Nieminen et al. 2011; Nybakk et al. 2002) or using radio- and GPS collars to follow large carnivores to estimate how many reindeer they kill (e.g. Mattisson et al. 2011, 2014a, 2014b, 2015; Pedersen et al. 1999). Despite these studies documenting the potential for carnivores to kill significant numbers of reindeer there remains considerable discussion, controversy and uncertainty about losses in specific areas.
4. In addition to the controversy about direct losses come further controversies around the impact that predation has on reindeer production. Estimating the impact of large carnivore depredation on reindeer production is made more complex by the findings that semi-domestic reindeer can also be locally exposed to the effects of high densities of reindeer which can potentially have negative effects on their food supply which in turn lowers the body condition of reindeer, and thereby their

reproductive output. They are also exposed to climatic variation, especially during winter (Aikio &Kojola 2014; Helle & Kojola 1993; Hobbs et al. 2012; Tveraa et al. 2003, 2007, 2012, 2013, 2014a,b). Both these effects can also increase reindeer vulnerability to large carnivore depredation. Despite intensive research there is still no clear agreement on the real impact of depredation (e.g. Ahman et al. 2014; Bardsen et al. 2017, Heikkinen et al. 2011).

5. Reindeer herding is also very vulnerable to loss of habitat due to infrastructure development and disturbance in reindeer range. The expansion of large carnivores into the reindeer herding areas during the last few decades is also often viewed as a form of habitat loss as the presence of carnivores may influence reindeer habitat use (Rivrud et al. 2018; Sivertsen et al. 2016).

6. Because of their shy nature and need for mobility to respond to an extreme environment semi-domestic reindeer are free-ranging throughout the year and are thus exposed to depredation throughout the year. The former traditional intensive herding practices have given way to more extensive forms of husbandry that also make it harder to protect reindeer (Helle & Jaakkola 2008). Their behaviour also makes it rather difficult to implement protection measures to lower the risk of depredation, although in areas where reindeer are in poor body condition there may be considerable scope to increase reproduction and lower depredation risk by lowering the reindeer density to more sustainable levels. Supplementary feeding in winter is used to variable degrees (Muutoranta & Maki-Tanila 2012).

7. As a result, wildlife management authorities in all three countries have used lethal control to regulate the size of the large carnivore populations in an effort to keep losses within tolerable levels (Anonymous 2007). This extends to policies in all countries that effectively excludes reproducing wolves, or at least minimises the numbers of wolves within the reindeer herding areas. In addition, economic compensation has been provided to cover the losses (Swenson & Andrén 2005). In Norway and Finland this is based on paying for losses, requiring at least partial documentation of large carnivore kills. However, because of the challenge with finding fresh carcasses for examination there is considerable uncertainty around losses such that managers have to use a certain amount of judgement when setting compensation payments. Questions have also been raised about the potential for the present system to perversely incentivise undesired practices (Naess et al. 2011, 2012). In Sweden, the system is based on paying for the risk associated with large carnivore presence (Zabel et al. 2014) which does not require documenting losses (apart from catastrophic events). Rather, the focus is on documenting the presence of reproducing populations of large carnivores.

Tables 14 - 17 show the numbers of reindeer compensated in Norway (average of 12,671 per year attributed to specific carnivores plus over 2,000 per year not attributed to any specific carnivore) and Finland (average of 4,714 per year). As mentioned above, no similar data are available for Sweden, but compensation payments have been made for the equivalent of between 20,000 and 40,000 (Anonymous 2007; Swenson & Andrén 2005).

In summary, the case of semi-domestic reindeer represents a very specific case of livestock depredation. Very little of the experience from other forms of livestock protection can be transferred to the case of reindeer. The levels of depredation are very high as compared to any other type of livestock found in Europe and there are very few mitigation measures available other than regulating the size of the large carnivore populations and paying compensation. Because reindeer are free-ranging all year they are much more vulnerable to depredation, climate and the carrying capacity of the vegetation than other livestock, thus requiring a holistic approach to their management.

One of the few parallels would be the case of free-ranging horses of northern Iberia (Llameza & Lopez-Bao 2015; Lopez-Bao et al. 2013).

10. LEGAL FRAMEWORKS FOR LARGE CARNIVORE MANAGEMENT

KEY FINDINGS

Large carnivore management is governed by the Bern Convention and the Habitats Directive at the European level.

There is much variation in the extent to which the different species are listed on the various annexes and appendices across Europe. The different annexes and appendices do not differ with respect to the required conservation goals for large carnivore conservation, but they do differ in the means which can be used to reach them.

For species which are listed as "strictly protected" there are strict requirements that must be fulfilled before individuals can be shot under derogation.

10.1. The major legal instruments

Two main instruments of international legislation are relevant for the management of large carnivores in Europe (Trouwborst 2010). The Bern Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) from 1979 now covers all 45 European countries that are members of the Council of Europe. Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) covers all 28 members of the European Union. Large carnivores are covered by both, although there are considerable differences between species and countries (Table 18).

By default, wolves, bears, and lynx are on annex II and annex IV (Table 18) of the Habitats Directive. Annex II requires countries to establish Natura 2000 sites for the species (we don't discuss annex 2 status here in detail but see Table 18). Wolverines are only present on annex II. Annex IV provides strict protection from killing. However, there is considerable variation for wolves, with a number of countries having total or partial exceptions, with wolves being covered by annex V instead. Annex V designation covers "species of community interest whose taking in the wild and exploitation may be subject to management measures". Spain regard wolves north of the river Duero as being annex V, and those south of the river Duero on annex IV, although there is uncertainty concerning where this boundary operates in the eastern parts of central Spain because the river obviously does not flow coast to coast (Trouwborst 2014). Greece similarly treat wolves north of the 39th parallel as being annex V and those south of the parallel to be annex IV. Finland treat wolves in the reindeer husbandry area as being annex V and those south of it as being annex IV. Estonia, Latvia, Lithuania, Poland, and Slovakia regard wolves as being annex V throughout their territories. Bears are on annex IV throughout the EU, and lynx are in annex IV in all countries apart from Estonia where they are annex V.

Under the Bern Convention, wolves, bears, and wolverines are by default on appendix II of "strictly protected" species. Lynx are on appendix III of "protected species", with the exception of the subspecies found in the western Balkans (*Lynx lynx balcanicus*) which is listed as appendix II. For wolves there are many exceptions, including countries that exclude wolves from their appendices totally (Bulgaria, Czech Republic, Finland, Latvia, Poland, Slovakia, Slovenia, Former Yugoslav Republic of Macedonia and others that regard them as being on appendix III instead (Lithuania, Spain). Some countries also excluded bears from their appendices (Czech Republic, Finland, Slovakia, Slovenia) or agreed to treat them as appendix III (Croatia). Ukraine opted for another variation by keeping bears and wolves on appendix II but reserving the right to exercise population control to limit damage.

The result is a somewhat bewildering array of different technicalities and nuances in the application of international legal instruments operating across Europe (Trouwborst 2010). Strictly speaking the international instruments are hierarchical, with the Bern Convention setting the frames, because the Habitats Directive is the EU's main instrument to fulfil its obligations under the Bern Convention. In other words, provisions under national legislation or under the Habitats Directive can have greater conservation ambition and offer stricter protection than under the Bern Convention, but not less. In any situation it will be the stricter / more ambitious legislation that applies. In most practical cases this will be the Habitats Directive, but for wolverines this will be the Bern Convention because they are not specifically listed under the Habitats Directive annex IV or V.

10.2. Setting the level of conservation ambition

Both instruments require countries to contribute towards the conservation of the species listed on the annexes and appendices. The specific annex or appendix which a species appears on does *not* affect the expected level of conservation commitment from any country. However, there is often a high degree of uncertainty concerning what this obligation actually means in terms of exact numbers of animals, their distribution, and their ecological impact. Even the Habitat Directive's concepts of Favourable Conservation Status (with associated Favourable Reference Population and Favourable Reference Range) is subject to discussion, despite being defined in the directive and explained in interpretation guidelines. The most detailed proposal for interpretation is outlined in the "Guidelines for population level management plans for large carnivores in Europe" prepared for the European Commission in the period 2006-2008 (Linnell et al. 2008) through a process involving consultation with many experts, stakeholders and the member states. These guidelines propose to formally relate the concept of favourable conservation status to the IUCN's red list criteria which are widely used in all countries to prepare their red data books, and which have a firm scientific underpinning. These guidelines currently have the status of "best practice" [2]. Despite this, there is still scholarly disagreement about interpretation of the expected level of national ambition with respect to favourable conservation status (e.g. Epstein 2016, Trouwborst et al. 2017a), which will remain until more case law accumulates from the Court of Justice of the European Union. There are also similar uncertainties with respect to the Bern Convention (Trouwborst et al. 2017b).

10.3. Limitations on the tools that can be used

The main difference represented by the specific annexes or appendices of the Habitats Directive and the Bern Convention relates to the circumstances when it is possible to kill, or otherwise remove, individuals. Article 16 of the Habitats Directive and Article 9 of the Bern Convention both list a set of criteria which must be fulfilled if a member state or party to the convention is going to deviate from the strict protection requirement of annex IV or appendix II, respectively. The basic requirements are that (1) it will not have a negative effect on the conservation status of the species, (2) that there is no satisfactory alternative solution available, and (3) that there is some utility or justification to the action.

Preventing "serious damage" to livestock is explicitly listed on both instruments as a potential justification for derogation, but there is a need to document that killing individuals will alleviate damage in a specific situation because of the scientific uncertainty about its effectivity. Furthermore, due to the nature of the formulation of the articles in the instruments this consideration only comes

---

[2] "*These guidelines represent best practice for the management of large carnivore populations and DG Environment accordingly recommends them to the authorities in the Member States. The guidelines are not legally binding but do constitute a reference point against which DG Environment will monitor the actions taken by the Member States in fulfilment of their obligations under the Habitats Directive*" - extract from letter signed by Patrick Murphy, then Head of Unit, in July 2008.

into play if the conditions of the lack of an alternative and the lack of negative impacts on the conservation status have already been demonstrated (see Epstein 2017; Linnell et al. 2018). Section 11 discusses the issue of existence of satisfactory alternatives, and the utility of lethal control to prevent serious damage in greater detail. Section 3 also presents data on the size of European large carnivore populations which is directly relevant for assessment of the impact of any impacts on population conservation status. A further constraint exists in the form Annex VI of the Habitats Directive and Appendix IV of the Bern Convention which list inhumane and non-selective methods of killing which are prohibited.

Therefore, the Bern Convention and the Habitats Directive cover both the *goals* of the conservations (in terms of conservation status) and the *means* that may be used to manage the animals. The major difference between the various annexes and appendices on which the different species occur in different regions / countries concern the means that can be used, rather than the goals.

A further constraint on non-lethal interventions that influence wild animals is provided by Directive 2010/63/EU on the Protection of Animals Used for Scientific Purposes. For species of conservation concern like large carnivores there are many restrictions on the live-capture and handling of individuals, related to both the procedures that can be adopted and the motivations for doing them. In short, potentially invasive or stressful actions are only permitted if they bring clear benefits to the animals. Despite its name, current interpretation of the directive does not restrict its application only to scientific actions, but also to management actions.

Table 18. Overview of the international conventions and treaties that the various countries of continental Europe have signed, with details of any species-specific exceptions

Country	Habitats Directive1	Bern Convention11	Bonn Convention
Albania		Y	Y
Andorra		Y	
Austria	Y	Y	Y
Belarus			Y
Belgium	Y	Y	Y
Bosnia and Herzegovina		Y	Y
Bulgaria	Y	Y[12]	Y
Croatia	Y	Y[13]	Y
Czech Republic	Y	Y[14]	Y
Denmark	Y	Y	Y
Estonia	Y[2]	Y	
Finland	Y[3]	Y[15]	Y
France	Y	Y	Y
Germany	Y	Y	Y
Greece	Y[4]	Y	Y
Hungary	Y	Y	Y
Italy	Y	Y	Y
Latvia	Y[5]	Y[16]	Y
Liechtenstein		Y	Y
Lithuania	Y[6]	Y[17]	Y
Luxembourg	Y	Y	Y
Moldova		Y	Y
Montenegro		Y	Y
Netherlands	Y	Y	Y
Norway		Y	Y
Poland	Y[7]	Y[18]	Y
Portugal	Y	Y	Y
Romania	Y	Y	Y
Russian Federation			MoU
San Marino			
Serbia		Y	Y
Slovakia	Y[8]	Y[19]	Y
Slovenia	Y	Y[20]	Y

Spain	Y9	Y21	Y
Sweden	Y10	Y	Y
Switzerland		Y	Y
The former Yugoslav Republic of Macedonia		Y22	Y
Turkey		Y23	
Ukraine		Y24	Y

Y = yes, MoU = has not ratified but takes part in some specific agreements through a memorandum of understanding.

Footnotes

1. By default, wolf, bear, lynx and wolverine are on annex II and wolves, bear and lynx are on annex IV of the habitats directive.
2. Estonia: exception for wolf, bear and lynx from annex II; wolf and lynx are on annex V.
3. Finland: exception for wolf, bear and lynx from annex II; wolf in reindeer husbandry area are on annex V.
4. Greece: exception for wolf north of the 39th parallel from annex II; wolf north of 39th parallel are on on annex V.
5. Latvia: exception for wolf and lynx from annex II; wolf on annex V.
6. Lithuania: exception for wolf from annex II; wolf on annex V.
7. Poland: exception so that wolf is placed on annex V.
8. Slovakia: exception so that wolf is placed on annex V.
9. Spain: exception for wolves from annex II north of river Duero; wolves north of river Duero are on annex V.
10. Sweden: exception for bears from annex II.
11. By default, wolves, bears and wolverines are on appendix II, lynx are on appendix III under the Bern Convention.
12. Bulgaria: wolves excluded from appendix II.
13. Croatia: bears will be treated as appendix III.
14. Czech Republic: wolves and bears excluded from appendix II.
15. Finland: wolves and bears excluded from appendix II.
16. Latvia: wolves excluded from appendix II.
17. Lithuania: wolves will be treated as appendix III.
18. Poland: wolves excluded from appendix II.
19. Slovakia: wolves and bears excluded from appendix II.
20. Slovenia: wolves and bears excluded from appendix II
21. Spain: wolves will be treated as appendix III.
22. Macedonia: wolves excluded from appendix II.
23. Turkey: wolves and bears excluded from appendix II.
24. Ukraine: wolves and bears remain on appendix II, but Ukraine reserves the right to exercise population control to limit damage.

11. MITIGATION OF CARNIVORE – LIVESTOCK CONFLICTS

KEY FINDINGS

Protecting livestock involves interrupting the process whereby carnivores find, approach, recognise, kill and consume livestock as prey.

The most effective measures to protect livestock involve robust electric fencing, night-time gathering of livestock into carnivore-proof enclosures, and the use of shepherds with livestock guarding dogs on open pastures.

For many husbandry systems some of these measures can be introduced without major changes, whereas for others there will need to be dramatic changes.

Although targeted and selective killing of large carnivores will always be needed to some degree, it is not possible to only rely on lethal control as this will not provide long-term solutions, nor be compatible with conservation legislation.

11.1. Conceptual introduction to mitigation

Humans have had a need to protect their livestock from large carnivores for millennia, ever since livestock were first domesticated. The oldest surviving descriptions come from ancient Rome and describe the use of livestock guarding dogs which are almost identical to present day practices. Throughout these millennia a large amount of experience has accumulated by trial and error and by cultural transfer rather than as a result of formal scientific experimentation. The same applies for recent developments and modifications to traditional systems – they have largely been driven by practitioners (both herders and conservationists). The technical and scientific literature now contains many descriptions of experience with different interventions, and there are a large number of studies that describe comparisons in losses between different herds or farms that use different methods. Unfortunately, there are very few well designed formal experiments (with randomisation, replication and control groups) in this field (Eklund et al. 2017; Graham et al. 2005, Treves et al. 2016; van Eeden et al. 2018) which reduces the strength of inference. As a result, the conclusions that we present here are based on very diverse sources, both experience- and science-based. However, the sheer volume of husbandry experience from so many different sources, combined with our rapidly expanding understanding of large carnivore behaviour, allows us to come with conclusions that we believe to be robust. Early publications have outlined these in greater detail (see Linnell et al. 1996, Linnell et al. 2012 and Breitenmoser et al. 2015).

Mitigating depredation requires understanding the ecology of predation. Predation consists of a 6 specific steps:

1. Searching for and locating an animal,
2. identifying this animal as potential prey,
3. approaching the animal closely enough to attack,
4. attacking the animal and establishing physical contact with it,
5. killing it, and
6. consuming it.

Depredation is basically similar, with the exception that prey may not be fully consumed, due either to surplus killing (Kruuk 1972) or to the risk of disturbance at the kill by a livestock guarding dog or herder. Opportunities exist at every step to interrupt the progression, to protect livestock, and to discourage future attacks.

Humans have developed ways to protect their livestock since antiquity, providing thousands of years of human experience. Table 19 places many mitigation measures in the context of the sequence of events that describe the predation process. The most common mitigation measures focus on 3 broad categories, those focused on carnivores (e.g. lethal control or non-lethal removal), those focused on livestock (husbandry methods) and those that pay economic compensation for losses. Addressing livestock depredation effectively inevitably requires use of all three approaches (Bangs et al. 2006), though the relative use of each varies greatly with circumstances.

11.2. Avoiding encounters

Throughout human history, humans have eliminated carnivores large enough to kill livestock (Boitani 1995). By the late 19th and early 20th centuries, this goal had almost been achieved for bears, wolves, lynx and wolverines across most of Europe, and resulted in a dramatic reduction in depredation. In the context of wildlife conservation, however, this approach is clearly incompatible with public opinion and existing national and international legislation.

11.2.1. Zoning

Zoning has often been raised as a potential compromise approach that separates carnivores and livestock geographically (Linnell et al. 2005). Zoning requires active regulation of carnivore distribution and density. For example, hunting and lethal control methods can be used to minimise carnivore densities in areas where livestock are given priority. Well-designed zoning can increase the predictability of carnivore depredation, which allows producers to plan their future needs and to adopt appropriate husbandry techniques. Zoning also enables a geographical prioritisation of economic instruments, such as those subsidizing mitigation measures (Rondinini & Boitani 2007). There are many studies from areas where livestock graze without protection that have shown that livestock losses are higher in areas where carnivores occur compared to areas where they do not, and that losses increase as carnivore density increases (e.g. Hobbs et al. 2012; Kavcic et al. 2013; Mabille et al. 2015, 2016). As such there is a basis for its use, and it is used on a broad scale in Norway (for all large carnivores; Krange et al. 2016), and Sweden / Finland (for wolves). Slovenia used to use it for bears, and Croatia for example actively prevents bears from colonising the islands (Linnell et al. 2005). Estonia also practices a differentiated management between islands and mainland.

However, there are a number of challenges with using it in Europe. Firstly, the massive home ranges of individual carnivores (100s or 1000s of km^2) and long dispersal distances made by young animals (100s of km; Linnell et al. 2005, Linnell 2015) dictate that zoning will work only at very large spatial scales and will never totally exclude carnivores from any zone. Most European countries are therefore way too small to be able to realistically zone carnivores out of a livestock area with any predictability. The other consequence of these spatial requirements is that there need to be massive areas allocated for the presence of carnivores in order to maintain populations that are viable or at favourable conservation status. These inter-connected areas will need to be in the order of tens or hundreds of thousands of square kilometres. In effect, very large parts of the European continent will be needed to achieve long term viability (Linnell et al. 2005, Linnell 2015; Linnell & Boitani 2012).

Another prerequisite for zoning is that wildlife managers must be able to control carnivore populations using methods that are economically and socially acceptable. Excluding large carnivores from areas therefore requires a constant removal of often large numbers of animals (e.g. wolves Chapron et al. 2003). In areas where large carnivore hunting is a tradition (Nordic and Baltic countries, parts of the western Balkans and Carpathians) there is experience of hunters using adaptive management approaches (adjusting quotas to respond to annual monitoring) within wildlife management institutional structures to regulate large carnivore populations at densities lower than carrying capacity to contain the extent of conflict (Herfindal et al. 2005, Linnell et al. 2010; Nilsen et al. 2012). However, in the cases where managers try to exclude carnivores totally from certain areas there is often a need for extraordinary methods (e.g. the use of out-of-season killing, or motorised vehicles) to remove highly mobile single individuals. Also, for some species like wolverines normal hunting is too logistically challenging and inefficient (Bischof et al. 2012) to regulate population size. This implies that hunters alone will not be able to enforce zoning policies, requiring the additional use of state authorities.

Killing large carnivores is both controversial with the public and professionals (Lute et al. 2018) and likely to face legal challenges where carnivores are listed as strictly protected on the Habitats Directive or the Bern Convention (Linnell et al. 2018). In fact, a recent analysis by Trouwborst (2018) has reasoned that zoning systems that seek to exclude, or severely reduce, large carnivore density as a matter of pre-emptive policy may not be compatible with legal obligations for such strictly protected species except potentially under very limited circumstances. For species with other annex designations there may be more freedom for interpretation. Non-lethal ways of removing large carnivores are largely inefficient and impractical. There is only place in captivity for a handful of individuals. Translocation of animals (capturing alive and releasing in another area) has been repeatedly shown to not work because of the tendency of released animals to return to the capture site (Linnell et al. 1997). Zoning is therefore a legally, socially, logistically and ecologically complex tool and must be approached with caution (Linnell et al. 2005).

However, this does not preclude a geographic differentiation in the way carnivores and livestock are managed as there obviously must be space for regional differences in approach and conditions. This especially concerns the choice of mitigation and adaptation measures that are used to protect livestock (see below).

11.2.2. Fine scaled differences in risk and encounters

Many studies have shown that some herds / farms suffer much greater losses than others within a region. A lot of this variation can be explained in terms of the probability of encounters between carnivores and livestock. Herds or farms that graze closer to areas with high carnivore *population* density for example will be impacted more than those further away. On an even finer scale those herds or farms that graze in the habitats preferred by *individual* carnivores (mainly forested areas or areas with dense scrub or riparian corridors and areas distant from roads and houses) are more likely to be attacked (Gazzola et al. 2005, Gula 2008; Kaartinen et al. 2009; Zingaro & Boitani 2017). This is because the chance of carnivores encountering these herds is greater, and because they feel more secure to make an attack. A range of analysis and mapping tools (i.e. Geographic Information Systems) exist to help predict those places where attacks are most likely (Marucco & McIntire 2010) and these can be used to prioritise the herds where protection measures are put into place, or to plan the development of different forms of herding / agriculture. An alternative approach takes advantage of the fact that carnivores tend to repeatedly attack the same herds / farms (e.g. Stahl et al. 2001). Some authors have therefore argued that protection measures can then be prioritised to these herds / farms that first experience attacks, because it is likely that they will continue to experience new attacks in the near future (Karlsson & Johansson 2010).

While it may be possible to predict the relative risk of herds and farms that are close to areas of stable carnivore presence it is important to bear in mind that the incredible dispersal capacity of these species (especially of the males) can lead to solitary individuals moving over massive areas several hundred kilometres from any areas of regular occurrence (e.g. Rosen & Bath 2009; Razen et al. 2016). These dispersing individuals can cause a lot of damage to livestock that they encounter, and it is therefore necessary to have rapid reaction plans that be set in place to respond to these situations and protect livestock.

11.3. Preventing recognition

11.3.1. The importance of wild prey

There have been many studies of the diet of large carnivores from across Europe (e.g. Newsome et al. 2016; Zlatanova et al. 2014 for wolves). These show enormous variation in the extent to which livestock appear in their diet – with studies showing everything from zero to 100% of wolf diet for example coming from livestock. Of course, the presence of an alternative wild prey is a prerequisite for large carnivores to avoid feeding on livestock. Despite wild herbivores being greatly reduced across Europe during the pre-20th century era, the last century has seen a dramatic expansion of wild herbivores across most of Europe such that there are currently multiple species of wild herbivore present in most parts of the continent (Map 6). In present day Europe the only areas where large carnivores are dependent on domestic livestock are at the extreme ends of the continent (Ciucci et al. 2018; Mattisson et al. 2011, 2014; Olson 2002; Pedersen et al. 2009; Torres et al. 2015). Lynx and wolverines are largely dependent on semi-domestic reindeer in northern Fennoscandia, and wolves are often very dependent on livestock in some areas of southern Europe (parts of Iberia, Italy, Albania, Greece).

Virtually all studies show that large carnivores have a very strong preference for wild prey (normally wild herbivores like roe deer, red deer, wild boar and moose) when they are present at medium to high density (e.g. Barja 2009; Imbert et al. 2016; Gervasi et al. 2014; Lagos & Barcena 2018; Meriggi & Lovari 1996, Odden et al. 2013; Sidorovich et al. 2003) such that depredation rates on livestock normally go down (although not to zero) when densities of wild prey increase. In such situations, virtually all studies show that large carnivores do not feed on livestock in proportion to their abundance and accessibility (i.e. livestock are normally more abundant than wild prey and are much easier to find, catch and kill). As a result, reducing levels of livestock depredation require cooperation with wildlife management authorities, foresters, hunters and landowners to maintain populations of wild large herbivores at reasonable levels.

Areas of southern Europe where wild prey are currently scare represent a challenge. Wild boar are present in most areas and are expanding, but there is plenty of scope for expanding roe deer and red deer populations, which may require reintroduction (Torres et al. 2015) and changes to hunting management. The situation in northern Fennoscandia is different as there are no wild herbivores which were once native that can be restored with the exception of wild reindeer, which are excluded because of the widespread practice of semi-domestic reindeer herding. There is therefore little chance that the dependence of large carnivores on livestock (semi-domestic reindeer and domestic sheep) can be reduced.

11.3.2. Fine scale issues

While there is a clear benefit of having larger populations of wild prey to reduce carnivore dependence on livestock at the large scale, there may be contrasting effects on the fine scale – such as the scale of an individual pasture. Some studies have shown that the grazing of sheep in the presence of locally high-density patches of wild prey may lead to increased risk of predation simply because it increases the risks of encounters between livestock and carnivores (Moa et al. 2006; Odden et al. 2008; Stahl & Vandel 2001). This underlines the importance of avoiding grazing in forests and dense scrublands.

11.3.3. Changing livestock species

The main mitigation strategy that causes predators to not consider livestock as prey is choosing large livestock species or breeds (Rook et al. 2004; Zimmermann et al. 2003). Using cattle instead of sheep or goats effectively excludes depredation by lynx and wolverine and greatly reducing vulnerability to wolves and bears. Significant benefits also come from switching to breeds or selectively breeding individuals that exhibit strong anti-predator behaviour, that are amenable to herding, or that are amendable to other mitigation measures (May et al. 2008). Much more research is needed into this strategy, especially concerning synergies with overarching agricultural and genetic-resource initiatives that focus on conserving traditional and rare breeds (Hall & Bradley 1995). However, choosing breeds that are compatible with husbandry strategies (such as tendency to form herds for sheep) is essential. Increasing protection for vulnerable juveniles of all livestock species by confining them to sheds or areas close to human habitation during, and immediately after, birth provides further benefits (Pimenta et al. 2017).

11.4. Aversive conditioning

The principle of aversive conditioning is that carnivores experiencing a negative stimulus when attacking livestock will associate the negative stimulus with livestock and not attack livestock again. The negative stimuli which have been tested include chemicals that induce vomiting (or at least taste bad) placed on carcasses, electric shock collars placed on predators, shooting predators with rubber bullets or exploding cracker shell, and using livestock guarding dogs (Smith et al. 2000; Shivik 2006; Hawley et al. 2009). Tests in captivity have taught individual carnivores to avoid eating carcasses but success at stopping them from killing living livestock has been minimal. Furthermore, no field trials have been successful (Landa et al. 1998; Smith et al. 2000; Shivik et al. 2003; Shivik 2006). To work, aversive condition needs to be applied continually to every individual carnivore of each species that depredates livestock. The hope that an individual might teach other members of its social group to avoid livestock has no field support, implying that every year all new members of each generation would need to be taught. It is therefore very unlikely to see such an approach having any success or practical application.

11.5. Lethal control

A common approach to resolving depredation problems has been to selectively remove those individual carnivores that prey on livestock, the so called “problem individuals” (Linnell et al. 1999; Treves 2009). Although this idea is appealing, such individuals often do not exist (Odden et al. 2002; Herfindal et al. 2005). Based on our current understanding of the issue it is most likely that problematic individuals will develop in situations where livestock are well guarded, as this requires the development of specific behaviours (such as jumping fences). In such cases there may well be short term benefits of lethally removing individuals (Stahl et al. 2001). However, there are many logistical problems associated with targeting them. Only when the individual is observed making a kill and is removed immediately, or where it can be tracked from the kill-site or killed on pastures or in barns can the right individual be removed for certain. In grazing systems where livestock are less well guarded it is likely that there will be less differences between individuals, although there may still be a tendency for certain sex or age classes to kill more livestock than others (Odden et al. 2002).

In many cases there are calls for less selective culls of multiple individuals in areas where livestock depredation occurs. There are relatively few analyses from Europe on this topic (e.g. wolves: Fernandez-Gil et al. 2016; lynx: Herfindal et al. 2005; bears: Sagør et al. 1997), although there are several wolf studies from North America. The results of some of these North American analyses have been hotly contested with different authors reaching different conclusions from the same data (e.g. Kompamiyets & Evans 2017, Poudyal et al. 2016; Wielgus & Peebles 2014). The current understanding is that there are few clearly documentable benefits of unselectively killing multiple individuals around an area with depredation unless the extent of killing significantly reduces the local population (Herfindal et al. 2015; Hobbs et al. 2012, Mabille et al. 2015). For example, one of the most extensive studies from the Rocky Mountains showed that clear benefits were only achieved by removing entire wolf packs. The application of lethal control on a level that has negative impacts on the carnivore population are likely to be very controversial with the wider public, and present many legal questions concerning the compatibility of the strategy with member states' obligations to achieve and maintain favourable conservation status or comply with the derogation criteria for those species that are strictly protected. Furthermore, several other studies have found that killing wolves can also lead to an increase in livestock losses in the same region (Fernandez-Gil et al. 2016) or on neighbouring farms (Santiago-Avila et al. 2018). Therefore, large scale application of unselective lethal control is a controversial method with very uncertain benefits (for sheep losses), and potentially undesirable side effects.

Even where individuals are removed, their territories will usually be filled rapidly, potentially by more than 1 juvenile animal, which can lead to even more conflicts (e.g. Robinson et al. 2008). So even if practiced, and even if there are benefits, it is an intervention that will need to be constantly applied year after year.

However, lethal control is highly popular with many livestock producers (Fernandez-Gil et al. 2016; Linkowski et al. 2017; Scasta et al. 2017; Sjölander-Lindqvist 2015), although the benefits of selective removal are probably mainly social / pyschological, in that livestock producers may feel appeased or empowered if they are allowed to kill the occasional, presumed problem individual (Linnell et al. 2018). Even this potential benefit is limited to particular segments of society, as other social groups find even this killing of carnivores controversial (Lute et al. 2018; Treves & Naughton-Treves 2005), such that using lethal control to address the conflict associated with livestock depredation may increase the wider social conflicts (Skogen 2015) and increase the divisions between livestock producers and other stakeholders (Jacobsen & Linnell 2016).

11.6. Preventing carnivore access to livestock

Most successful mitigation measures operate at this stage of the predation process. The vast majority of current interventions focus on two approaches that have produced effective results; modern electric fencing and traditional shepherding systems.

11.6.1. For sheep and goats on fields or other fenced pastures

In many situations in Europe, livestock are grazed on permanent pastures that are on fields, in forest openings, or alpine meadows. Normally livestock movements are constrained by simple wire netting fences or lightweight electric fences that hinder movement by livestock but are permeable to carnivores. While containing livestock in this way prevents a great deal of depredation by reducing chance encounters (Swenson & Andrén 2005) it is relatively simple to upgrade the fencing to carnivore-proof electric fencing. The best quality fences for permanent pastures consists of 5 – 7 strands of high tensile wire and very high voltage (Box 1) and is effective for many species of carnivore (e.g., wolves, bears). It is also possible to use lighter and more portable electric mesh fencing, which can be used on more open pastures (such as alpine pastures and heathlands), although these may not be so robust or long-lived. Even though some carnivores still enter these enclosures, losses are greatly reduced compared to free-ranging sheep. It is also possible to place livestock guarding dogs inside fences (both electrified and non-electrified). They will both discourage carnivores from entering and minimise losses should they enter. When livestock guarding dogs are kept in fences there are also fewer problems with undesired dog behaviour towards people and other wildlife.

Initial investment costs for electric fences are high, but maintenance costs are relatively low apart from keeping vegetation levels low around the base. In countries with high labour costs, carnivore-proof electric fencing around permanent pastures will probably be one of the best solutions to depredation. Fortunately, there is now ample experience from multiple projects, including many LIFE funded projects (Salvatori 2012), into the designs that are most successful. However, multiple studies have demonstrated problems with poor designs, incorrect construction and poor maintenance of fences (Frank & Eklund 2017; Wam et al. 2003) indicating that it is crucial to provide technical assistance to farmers to ensure that fences are correctly constructed and maintained. Additional safety can be obtained if livestock are brought indoors at night or are placed in an even more securely constructed night-time enclosure because most attacks occur at night (Mattiello et al. 2012; Stoynov et al. 2014; van Liere et al. 2013).

Electric fencing also represents a tried-and-tested effective defence to prevent bears attacking beehives (Svensson et al. 1998). Because solar panels can effectively charge the fences, they can be used in a wide range of situations.

11.6.2. For sheep or goats on open pasture

Traditional shepherding systems in Europe (as well as Asia and Africa) (Box 2) have always utilised shepherds, often accompanied by both guarding and herding dogs, while they graze during daytime and enclose the livestock into corrals or sheds at night (Lescureux & Linnell 2014; Linnell & Lescureux 2015). Protection is provided by the presence of the shepherd and the dogs during day, and by the physical structure of the night-time enclosure and the proximity of the shepherd and dogs at night (Espuno et al. 2004; Mertens et al. 2001; Ogada et al. 200). Some extensive systems, especially those associated with nomadic pastoralists, have no fixed night-time enclosures. Instead livestock bed as a tight group close to a campsite and are guarded by shepherds and dogs at night. These traditional systems have permitted livestock production in landscapes with high densities of large carnivores for millennia. Many studies have demonstrated their success (Espuno et al. 2004; Kruuk 1980; Ogada et al. 2003; Smith et al. 2000a; Rigg et al. 2011; Woodroffe et al. 2007) and the negative consequences of lax husbandry (e.g. Wang & Macdonald 2006).

These traditional husbandry systems are still applicable today, with minimal changes. One change is in the availability of specialised livestock guarding dogs beyond the areas of their origin. The many breeds, which were developed in central / southern Europe and the Middle East (Coppinger & Schneider 1995; Rigg 2001, Linnell & Lescueux 2015), are currently being spread around the world (Potgieter et al. 2016; Ostavel et al. 2009). Furthermore, there is now better knowledge about the best techniques for bonding with livestock, integrating dogs into flocks, and correcting undesired behaviour. Secondly, new alternatives exist for constructing night-time enclosures, including chain-link and electric fences. New materials also exist to construct mobile light-weight electric fences suitable for nomadic systems (Mertens et al. 2002) as well as very solid permanent structures.

Unfortunately, the traditional knowledge of how to effectively protect livestock from carnivores has been lost in many areas during periods where large carnivores were absent or when livestock production was abandoned for other forms of agriculture (e.g. Kikvidze & Tevzadre 2015). In the absence of predators many husbandry systems evolved where livestock were grazed in the absence of herding and guarding. There have been many projects in recent years that have worked to recover traditional systems and teach herders how to adapt to the return of large carnivores (e.g. Alvares et al. 2015, Anon 2015).

The main problem with the application of traditional herding systems under modern conditions is that they are labour intensive. In systems where livestock are milked, the addition of guarding measures comes at relatively low extra costs because the livestock need to be herded for twice daily processing anyway. Where meat is the main product, guarding has a high additional cost because production can, in theory, exist without shepherds if carnivores are absent. Development of solid night enclosures will eliminate the need for herders to be awake all night. The socio-economic status of the country will determine the relative costs of labour intensive vs technical solutions. The benefits of having large vs small herds with respect to the risk of carnivore attacks appear mixed, making the impact of adopting economies of scale unclear. Because depredation can have seasonal patterns (e.g. Kaczensky 1999) or can be confined to certain age classes of livestock means that the use of mitigation measures can be adjusted to seasonal needs, thereby providing potential savings. A careful spatial analysis of conflict risk can also help focus the appropriate mitigation measures into the correct areas (e.g. Treves et al. 2004; Inskip & Zimmermann 2009; Marucco & McIntire 2010).

Secondary impacts of changes in livestock husbandry to livestock growth and health, and the impacts of livestock on vegetation are also important. Livestock allowed to graze freely and those that are shepherded and confined at night have different activity patterns and different access to forage. Livestock with access to abundant forage during the day may be able to compensate for night-time confinement (e.g. Iason et al. 1999) but confinement and herding will probably reduce growth rates in other circumstances. In extremely hot areas there may be additional challenges if livestock tend to graze during the cool of the night. Changing the breed of livestock to one which has behavioural adaptations that are more compatible with the husbandry system (e.g. flocking behaviour) might be necessary. Furthermore, changes in grazing pressure caused by fencing or herding will probably increase grazing pressure in some areas and decrease pressure in others. The resultant impacts on vegetation biomass and biodiversity may be complicated and hard to predict. However, forms of husbandry where shepherds are more continually present may also have other benefits for livestock production. This includes a faster reaction time to accidents and symptoms of disease or illness, and the ability to more directly control where livestock graze to avoid conflicts with forestry and agriculture. It is therefore likely that close shepherding will lead to a reduction in mortality to all causes, not just predation. In this context it is important to point that mortality causes due to sources other than predators tend to dominate in most husbandry systems, at least for sheep and goats.

Devices (often high tech) that produce loud sounds and lights to scare carnivores, and flag-lines ("fladry") for wolves, may deter predators from entering specific pastures in the short term (Musiani et al. 2005). Nonetheless, no real evidence supports more than a temporary respite from depredation because carnivores become habituated (Shivik et al. 2003; Shivik 2006; Bangs et al. 2006), although these devices may be useful for rapid deployment in crisis situations to buy time to introduce more effective measures. It is also clearly impossible to use such approaches over large areas.

11.7. Conclusions about mitigation measures

Among the range of methods that exist various combinations of electric fencing, livestock guarding dogs and continual shepherding offer the best results. For production systems where livestock are already fenced the upgrading to electric fencing, with or without the addition of a livestock guarding dog, offers a practical and effective approach with minimal change. For free-ranging systems that are already herded greater protection can be added through the use of livestock guarding dogs and night-time enclosures without too dramatic changes. The greatest challenge is represented by those systems where livestock free-graze on open pasture without fencing or shepherding. These systems require major changes to husbandry, either moving towards being fenced behind electric fencing or continually herded by shepherds with livestock guarding dogs and potentially night-time enclosures. It is important to realise that no system will ever be 100% successful, but experience from across Europe shows that correctly implemented protection measures can dramatically reduce losses to predators. There is currently a great deal of experience from across Europe on how to mitigate large carnivore attacks on livestock (see Table 20 for web resources).

Table 19. The behavioural steps in a predation sequence with the associated mitigation measures that can interrupt the escalation of attack. Those measures of greatest relevance for modern-day Europe are highlighted in bold, with the number of asterixis (1-3) reflecting the existing state of knowledge about its effectivity and practicality. Other measures are listed for completeness, but they are either ineffective or impractical in the European context

Behaviour	Mitigation measure	Mechanism (theory / assumption)
Search	Eradication of carnivores	If all carnivores are removed there will be no encounters – historically the measure of choice, but obviously not suitable within a modern conservation context.
↓	Zoning	On a scale measured in 10.000s of km^2 it is possible to reduce depredation by avoiding livestock production in regions with high density carnivore populations, based on carnivore distribution or culling where this is legally permissible.
↓	**Placement of livestock in the landscape** *	On a finer scale it is possible to avail of carnivore patterns of habitat selection to place flocks in parts of the landscape that carnivores use less, or to invest more heavily in mitigation measures in high risk areas.
Identify	Aversive conditioning	The principle is to provide negative experiences associated with livestock that should lead the carnivores to avoid regarding the livestock as suitable prey.
↓	**Selective removal***	If depredation is due to a few specific problem individuals, their selective removal should in theory reduce depredation.
↓	**Different livestock species****	Moving from small stock (sheep and goats) to large stock (cattle, water buffalo) production will prevent depredation by many smaller carnivores.
↓	**Promote wild prey****	The existence of wild alternative prey is a prerequisite for effective depredation mitigation. The greater the availability of wild prey, the less likely it is that carnivores will depend on livestock.
Approach	**Avoid certain habitats***	Keeping livestock in open habitats as opposed to closed habitats and away from stalking cover may discourage many species in their final approach.
↓	**Carnivore proof fencing*****	The use of carnivore proof enclosures (e.g. electric fences) around whole pastures and / or for night time enclosures effectively decreases depredation.
↓	Lights, sirens	The principle is that these devices will scare carnivores away as they make their final approach.

➜	**Livestock guarding dogs*** **	These dogs will remain with the flock and either will drive the carnivores away or interfere enough with their attack sequence so that shepherds can arrive.
➜	**Shepherds*** **	Most carnivores will be deterred from their attack by the arrival of human shepherds.
Attack	**Livestock guarding dogs*** **	Dogs will interfere with the carnivore's attack, preventing it from completing the kill.
➜	**Shepherds*** **	Shepherds will interfere with the carnivore's attack, preventing it from completing the kill.
Kill	Protective collars	In principle these collars will form a physical barrier to the carnivore's bite.
➜		
Consume	**Livestock guarding dogs*** **	Dogs will prevent the carnivore from being able to consume it's kill by driving it away.
	Shepherds* **	Shepherds will prevent the carnivore from being able to consume it's kill by driving it away.

Table 20. Available web resources on livestock protection measures

Carnivore Damage Prevention News newsletter [all issues can be found in http://lcie.nina.no/Publications.aspx]	EN
LIFE Arctos " Brown Bear Conservation: Coordinated Actions in the Alpine and Apennine Range " [http://www.life-arctos.it/home.html]	EN, IT
LIFE Medwolf " Best practice actions for wolf conservation in Mediterranean-type areas " [http://www.medwolf.eu/]	EN, IT, PT
LIFE WOLFNET [http://www.lifewolf.net/it/component/content/]	
LIFE Extra "Improving the conditions for large carnivore conservation: a transfer of best practice" [http://www.lifextra.it/]	EN, IT, BG, RO, GR
LIFE Co-Ex "Improving coexistence of large carnivores and agriculture in southern Europe "[http://www.life-coex.net/]	EN, FR, HR, IT, ES, PT
LIFE SLOWOLF " Conservation and surveillance of the conservation status of the wolf (Canis lupus) population in Slovenia " [http://www.volkovi.si/]	EN, SL
LIFE CRO-WOLF "Protection and Management of Wolf Populations in Croatia" [http://www.life-vuk.hr/vuk/]	HR
LIFE DINALPS “Population level management and conservation of brown bear in northern Dinaric Mountains and the south-eastern Alps”	HR, SLO, EN, DE, IT
LIFE Lynx https://www.lifelynx.eu/	SLO, EN
Sweden's Wildlife Damage Centre [http://www.viltskadecenter.se/]	SE
Norway's Wildlife Damage Centre [http://www.bioforsk.no/ikbViewer/page/prosjekt/hovedtema?p_dimension_id=19579&p_menu_id=19593&p_sub_id=19578&p_dim2=19580]	NO
AGRIDEA – Swiss Livestock Protection Information [http://www.herdenschutzschweiz.ch/]	FR, DE, IT
Protect your livestock [http://www.protezionebestiame.it/il-progetto/]	IT
Let your livestock be safe [http://www.saugiavis.lt/en/]	LT, EN
Large Carnivore Initiative for Europe – searchable database of publications on livestock protection in many languages [http://lcie.nina.no/Publications.aspx]	EN
European Commission’s Large Carnivore website [http://ec.europa.eu/environment/nature/conservation/species/carnivores/index_en.htm]	EN

12. COMPENSATION PAYMENTS AND OTHER ECONOMIC INSTRUMENTS

KEY FINDINGS

Economic instruments should primarily focus on stimulating and enabling livestock protection measures.

Theory predicts that payment for risk should work better than payment for damage, although there is some degree of opposition to this from users.

However, there will always be a need for ex post facto compensation to deal with extreme events and areas of low intensity or unpredictable conflict.

The payment of compensation for livestock losses due to depredation is a common technique intended to protect livestock producers from economic losses and to increase public acceptance of conflicts (Fourli 1999; Nyhus et al. 2005; Ravenelle & Nyhus 2017). Compensation is paid by different agencies in different countries, including the state, non-government organizations, or agricultural insurance schemes. Compensation is usually paid only for depredation by carnivores of specific species, requiring identification of the responsible species. In addition, conditions may be attached to the payments, such as certain animal husbandry requirements. The assumption is that receiving an economic compensation increases farmer tolerance of carnivore depredation. This assumption has rarely been demonstrated (Boitani et al. 2010; Naughton-Treves et al. 2003; Gusset et al. 2009) and its validity varies with socio-economic and cultural context (Maclennan et al. 2009).

Compensation schemes are expensive (as they have high transaction costs associated with validating and processing claims in addition to the amounts paid) and controversial (where depredation must be documented there can often be conflicts over determining cause of death). Finding all livestock killed by carnivores and having them inspected rapidly to verify cause of death is difficult. It is also often claimed that compensation schemes reward passivity and do not motivate producers to adopt effective mitigation strategies (Nyhus et al. 2005; Bulte & Rondeau 2006). In the worst case there are some analyses that show that compensation payments actually help maintain unsustainable strategies (Næss et al. 2011; Skonhoft et al. 2017). Insurance programs appear to work in some countries, where producers pay premiums to insure their stock against losses. Even when the insurance system is subsidised, it induces a sense of responsibility into the system. Nonetheless, theory and experience suggest that financial mechanisms that pay incentives *ex ante* for carnivore presence (paying for risk) rather than paying *ex post facto* for damage should work better (Ferraro & Kiss 2002; Schwerdtner & Gruberb 2007; Skonhoft 2017; Zabel & Holm-Müller 2008). These *ex ante* systems fit into a wider discourse within small scale agriculture that suggests payment for activities and ecosystem services is favoured over payment for conventional agricultural products (e.g. Brunstad et al. 2005). Such incentive systems encourage depredation prevention rather than documentation and have significantly lower transaction costs than compensation and insurance systems. The major cost for incentive systems is the need to map carnivore distributions accurately (as major determinants of risk) and to agree on a rate of payment that is fair. The experience from Sweden suggests that the *ex ante* system delivers conservation outcomes (Persson et al. 2015), however, attempts to introduce the system to Norway and Finland have been met with protests, and one study has shown that Portuguese herders were also negative to the idea (Milheiras & Hodge 2011) implying that the expectations of the *ex post* system have become entrenched.

The classical *ex post facto* system may still have a role within an incentive system. Payments may be needed when depredation occurs outside the known range of certain carnivore species in areas where livestock producers could not expect to need mitigation measures. Payment might also be needed for extreme depredation events despite the use of effective measures or in areas where losses are so low that adopting protection measures is not economically viable.

Irrespective of which approach is used, some form of economic support will be needed to help livestock producers overcome the additional costs that large carnivores cause them. A number of studies have examined the extent to which Rural Development funding under EAFRD can be used to support the costs of mitigation measures (Marsden et al. 2016). These studies have identified a wide range of possibilities for using EAFRD funding to support activities related to protecting livestock from large carnivores. In addition, there have been many LIFE project's funded by the European Union which have provided both direct and indirect support to farmer's trying to adapt to the presence of large carnivores (see Salvatori 2012; Silva 2013). Many relevant resources are present on the website of the European Commission's large carnivore stakeholder platform (http://ec.europa.eu/environment/nature/conservation/species/carnivores/index_en.htm).

13. THE NEED FOR INTEGRATED LIVESTOCK PROTECTION SYSTEMS

KEY FINDINGS

Addressing large carnivore impacts on livestock requires a main focus on livestock protection measures, but targeted and selective lethal control and economic compensation will also often be needed in specific situations

The conflict with large carnivores cannot be seen in isolation from other aspects of rural policy. There is a need to integrate livestock protection policies with wider rural policies to stimulate viable small scale livestock production systems.

13.1. Integrating tools for coexistence

We have described three broad approaches to deal with large carnivore depredation on livestock, (1) *non-lethal protection measures* that prevent large carnivores from killing livestock, (2) *lethal approaches* where large carnivores are killed, and (3) *economic instruments* that compensate herders for their losses. In the present day where both public opinion and legislation are highly supportive of large carnivore conservation it is clearly not possible to resort to only lethal control of large carnivores. As long as society has joint goals of supporting both large carnivore conservation and small-scale livestock production in marginal areas the primary focus will have to be non-lethal protection measures for livestock. The extent to which this will require changes to how producers keep their livestock will vary from minimal to major, but there are feasible approaches for almost all situations given the appropriate economic support and technical assistance. Lethal control will also always be needed to some extent, at a minimum to remove problematic individuals that learn to evade protection measures, and in some circumstances to locally lower large carnivore density to acceptable levels. Compensation for losses, either as *ex post*, *ex ante* or insurance will also be needed for several situations, especially for cases where depredation occurs despite the use of protection measures, or when it occurs in unpredictable areas. Therefore, an integrated system to manage large carnivore depredation on livestock will require the appropriate integration of non-lethal protection measures, lethal reaction, and compensation. The relative focus on these components will depend on the legal framework, the form of livestock production, the risk of depredation, the carnivore species present and the local social context.

13.2. A realistic understanding of coexistence

There is also a need for realism with respect to what can be achieved in terms of reducing social conflicts (Linnell 2013). The conflicts over large carnivores, and especially wolves, are becoming so deeply engrained in agricultural and rural politics, and represent so many even deeper societal divisions, that it is unlikely that any policy will provide consensus among all stakeholders. Any set of policies will be controversial among some stakeholders. However, there are many dangers in judging public opinion only from the media as experience has shown that the high conflict stories that tend to get media attention may not reflect the more nuanced and diverse views that exist among both rural and urban publics. When all decisions are likely to be controversial it is essential that decision making processes maintain broad societal legitimacy that manage to balance the inputs of diverse experts, key stakeholders and the public before making clear decisions. "Coexistence" with large carnivores will never be a harmonious state and the difficult issues will never be "solved". There will always be negative impacts of large carnivores on the interests of some stakeholders and there will always be some conflicts between different stakeholders with opposing objectives about how they should be managed. The goal for decision making and on-the-ground agricultural and wildlife managers is to reduce these impacts to tolerable levels by adapting practices to their presence and to contain the conflicts within acceptable limits using a range of governance tools (Linnell 2013; Carter & Linnell). One of the intrinsic problems in large carnivore management is that of scale. The ecology of the species dictates the need for large scale coordination of actions across very large areas (Linnell & Boitani 2012) however, the conflicts associated with them require a strong focus on finding a diversity of local solutions to local contexts (Linnell 2015). Bridging the gap between these scales requires the use of novel mechanisms with broad institutional and multi-sectorial cooperation.

13.3. Policy alignment for coexistence

Adapting to the presence of large carnivores may be expensive and either require changes to animal husbandry practices that have become established for several generations or maintaining traditional systems in the face of market forces that are pushing for greater economic effectivity, and intrinsically more vulnerability to depredation. Funding for livestock protection measures is available from many sources, including EAFRD and LIFE. Accessing these funds to support livestock requires alignment of objectives with other sectors such as nature conservation and tourism. When done in the right way the protection measures needed to protect livestock from large carnivores can be perfectly compatible with both these other sectorial interests. Because conflicts over large carnivores are intrinsically intertwined with other issues of concern to rural residents, it is impossible to resolve the “livestock conflict” without also addressing the many other issues that influence rural communities facing the challenges of the 21st century. The need to align the mechanisms and policies from these multiple sectors is crucial for the maintenance of agricultural production, rural communities and biodiversity conservation (Hinojosa et al. 2018). There are many potential synergies that can found, for example between large carnivore conservation and high nature value farming if instruments are properly aligned, but also many potential conflicts and lost opportunities that can generated if they are not.

REFERENCES

- Ahman, B., Svensson, K. & Ronnegard, L. (2014) High Female Mortality Resulting in Herd Collapse in Free-Ranging Domesticated Reindeer (Rangifer tarandus tarandus) in Sweden. *Plos One,* **9**.
- Aikio, P. & Kojola, I. (2014) Reproductive rate and calf body mass in a north-boreal reindeer herd: effects of NAO and snow conditions. *Annales Zoologici Fennici,* **51,** 507-514.
- Alvares, F., Blanco, J.C., Salvatori, V., Pimenta, V., Barroso, I. & Ribeiro, S. (2015) *La predación del lobo sobre el ganado vacuno: Caracterización del conflicto y propuestas para reducirlo*.
- Andren, H., Persson, J., Mattisson, J. & Danell, A.C. (2011) Modelling the combined effect of an obligate predator and a facultative predator on a common prey: lynx Lynx lynx and wolverine Gulo gulo predation on reindeer Rangifer tarandus. *Wildlife Biology,* **17,** 33-43.
- Anonymous (2007) *Rovdjuren och deras förvaltning: betänkande av utredingen om de stora rovdjuren*. Statens Offentliga Utredningar SOU 207:89, Stockholm.
- Anonymous (2015) *Manual prevencao de prejuizos por predadores no gado*. LIFE Med-Wolf.
- Aronsson, M. & Persson, J. (2017) Mismatch between goals and the scale of actions constrains adaptive carnivore management: the case of the wolverine in Sweden. *Animal Conservation,* **20,** 261-269.
- Bangs, E.E., Jimenez, M.D., Niemeyer, C., Fontaine, J.A., Collinge, M., Krsichke, R., Handegard, L., Shivik, J., Sime, C., Nadeau, S., Mack, C.M., Smith, D.W., Asher, V. & Stone, S. (2006) Non-lethal and lethal tools to manage wolf-livestock conflict in the northwestern United States. *Proceedings of the Vertebrate Pest Conference,* **22,** 7-16.
- Bardsen, B.J., Naess, M.W., Singh, N.J. & Ahman, B. (2017) The Pursuit of Population Collapses: Long-Term Dynamics of Semi-Domestic Reindeer in Sweden. *Human Ecology,* **45,** 161-175.
- Barja, I. (2009) Prey and prey-age preference by the Iberian wolf Canis lupus signatus in a multiple-prey ecosystem. *Wildlife Biology,* **15,** 1-8.
- Bautista, C., Naves, J., Revilla, E., Fernández, N., Albrecht, J., Scharf, A.K., Rigg, R., Karamanlidis, A.A., Jerina, K., Huber, D., Palazón, S., Kont, R., Ciucci, P., Groff, C., Dutsov, A., Seijas, J., Quenette, P.Y., Olszańska, A., Shkvyria, M., Adamec, M., Ozolins, J., Jonozovič, M. & Selva, N. (2017) Patterns and correlates of claims for brown bear damage on a continental scale. *Journal of Applied Ecology,* **54,** 282–292
- Benayas, J.M.R., Martins, A., Nicolau, J.M. & Schulz, J.J. (2007) Abandonment of agricultural land: An overview of drivers and consequences. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources,* **2**.
- Bischof, R., Nilsen, E.B., Broseth, H., Maennil, P., Ozolins, J. & Linnell, J.D.C. (2012) Implementation uncertainty when using recreational hunting to manage carnivores. *Journal of Applied Ecology,* **49,** 824-832.
- Bisi, J., Kurki, S., Svensberg, M. & Liukkonen, T. (2007) Human dimensions of wolf (Canis lupus) conflicts in Finland. *European Journal of Wildlife Research,* **53,** 304-314.
- Bjärvall, A. & Franzen, R. (1981) Mortality transmitters - an important tool for studying reindeer calf mortality. *Ambio,* **10**.
- Bjärvall, A., Franzén, R., Nordkvist, M. & Åhlman, G. (1990) *Reindeer and carnivores: carnivore's effect on reindeer husbandry [Renar och rovdjur: rovdjurens effekter på rennäringen]*. Naturvårdsverket förlag, Solna.

- Blanco, J.C. & Cortes, Y. (2009) Ecological and Social Constraints of Wolf Recovery in Spain. *A new era for wolves and people: wolf recovery, human attitudes, and policy* (eds M. Musiani, L. Boitani & P.C. Paquet), pp. 41-. University of Calgary Press, Calgary.
- Boitani, L. (1995) Ecological and cultural diversities in the evolution of wolf human relationships. *Ecology and conservation of wolves in a changing world* (eds L.N. Carbyn, S.H. Fritts & D.R. Seip), pp. 3-12. Canadian Circumpolar Institute, Alberta, Canada.
- Breitenmoser, U., Angst, C., Landry, J.M., Breitenmoser-Würsten, C., Linnell, J.D.C. & Weber, J.M. (2005) Non-lethal techniques for reducing depredation. *People and wildlife: conflict or coexistence?* (eds R. Woodroffe, S. Thirgood & A. Rabinowitz), pp. 49-71. Cambridge University Press, Cambridge.
- Brunstad, R.J., Gaasland, I. & Vardal, E. (2005) Multifunctionality of agriculture: an inquiry into the complementarity between landscape preservation and food security. *European Review of Agricultural Economics,* **32,** 469-488.
- Bulte, E.H. & Rondeau, D. (2006) Why compensating wildlife damages may be bad for conservation. *Journal of Wildlife Management,* **69,** 14-19.
- Caniglia, R., Fabbri, E., Mastrogiuseppe, L. & Randi, E. (2013) Who is who? Identification of livestock predators using forensic genetic approaches. *Forensic Science International-Genetics,* **7,** 397-404.
- Carter, N.H. & Linnell, J.D.C. (2016) Co-adaptation is key to coexisting with large carnivores. *Trends in Ecology and Evolution,* **31,** 575-578.
- Chapron, G., Kaczensky, P., Linnell, J.D.C., von Arx, M., Huber, D., Andrén, H., López-Bao, J.V., Adamec, M., Álvares, F., Anders, O., Balčiauskas, L., Balys, V., Bedő, P., Bego, F., Blanco, J.C., Breitenmoser, U., Brøseth, H., Bufka, L., Bunikyte, R., Ciucci, P., Dutsov, A., Engleder, T., Fuxjäger, C., Groff, C., Holmala, K., Hoxha, B., Iliopoulos, Y., Ionescu, O., Jeremić, J., Jerina, K., Kluth, G., Knauer, F., Kojola, I., Kos, I., Krofel, M., Kubala, J., Kunovac, S., Kusak, J., Kutal, M., Liberg, O., Majić, A., Männil, P., Manz, R., Marboutin, E., Marucco, F., Melovski, D., Mersini, K., Mertzanis, Y., Mysłajek, R.W., Nowak, S., Odden, J., Ozolins, J., Palomero, G., Paunović, M., Persson, J., Potočnik, H., Quenette, P.-Y., Rauer, G., Reinhardt, I., Rigg, R., Ryser, A., Salvatori, V., Skrbinšek, T., Stojanov, A., Swenson, J.E., Szemethy, L., Trajçe, A., Tsingarska-Sedefcheva, E., Váňa, M., Veeroja, R., Wabakken, P., Wölfl, M., Wölfl, S., Zimmermann, F., Zlatanova, D. & Boitani, L. (2014) Recovery of large carnivores in Europe's modern human-dominated landscapes. *Science,* **346,** 1517-1519.
- Ciucci, P. & Boitani, L. (1998) Wolf and dog depredation on livestock in central Italy. *Wildlife Society Bulletin,* **26,** 504-514.
- Ciucci, P., Artoni, L., Crispino, F., Tosoni, E. & Boitani, L. (2018) Inter-pack, seasonal and annual variation in prey consumed by wolves in Pollino National Park, southern Italy. *European Journal of Wildlife Research,* **64**.
- Clark, J.D., Huber, D. & Servheen, C. (2002) Bear reintroductions: lessons and challenges. *Ursus,* **13,** 335-346.
- Coppinger, R. & Schneider, R. (1995) Evolution of working dogs. *The domestic dog* (ed. J. Serpell), pp. 21-47. Cambridge University Press, Cambridge.
- Defrancesco, E., Gatto, P. & Mozzato, D. (2018) To leave or not to leave? Understanding determinants of farmers' choices to remain in or abandon agri-environmental schemes. *Land Use Policy,* **76,** 460-470.
- Eklund, A., Lôpez-Bao, J.V., Tourani, M., Chapron, G. & Frank, J. (2017) Limited evidence on the effectiveness of interventions to reduce livestock predation by large carnivores. *Scientific Reports,* **7**.

- Epstein, Y. (2016) Favourable Conservation Status for Species: Examining the Habitats Directive's Key Concept through a Case Study of the Swedish Wolf. *Journal of Environmental Law,* **28,** 221-244.
- Epstein, Y. (2017) Killing wolves to save them? Legal responses to "tolerance" hunting in the European Union and United States. *Review of European Community and International Environmental Law,* **26,** in press.
- Espuno, N., Lequette, B., Poulle, M.L., Migot, P. & Lebreton, J.D. (2004) Heterogeneous response to preventive sheep husbandry during wolf recolonization of the French Alps. *Wildlife Society Bulletin,* **32,** 1195-1208.
- Farinella, D., Nori, M. & Ragkos, A. (2017) Changes in Euro-Mediterranean pastoralism: which opportunities for rural development and generational renewal? . *Proceedings of the 19th Symposium of the European Grassland Federation* (eds C. Porqueddu, A. Franca, G. Lombardi, G. Molle, G. Peratoner & A. Hopkins), pp. 23-36. Organising Committee of the 19th Symposium of the European Grassland Federation,, Alghero, Italy
- Fernandez-Gil, A., Naves, J., Ordiz, A., Quevedo, M., Revilla, E. & Delibes, M. (2016) Conflict Misleads Large Carnivore Management and Conservation: Brown Bears and Wolves in Spain. *Plos One,* **11**.
- Ferraro, P.J. & Kiss, A. (2002) Direct payments to conserve biodiversity. *Science,* **298,** 1718-1719.
- Fourli, M. (1999) *Compensation for damage caused by bears and wolves in the European Union*. European Union.
- Frank, J. & Eklund, A. (2017) Poor construction, not time, takes its toll on subsidised fences designed to deter large carnivores. *Plos One,* **12**.
- Gazzola, A., Bertelli, I., Avanzinelli, E., Tolosano, A., Bertotto, P. & Apollomio, M. (2005) Predation by wolves (Canis lupus) on wild and domestic ungulates of the western Alps, Italy. *Journal of Zoology, London,* **266,** 205-213.
- Gervasi, V., Nilsen, E.B., Odden, J., Bouyer, Y. & Linnell, J.D.C. (2014) The spatio-temporal distribution of wild and domestic ungulates modulates lynx kill rates in a multi-use landscape. *Journal of Zoology,* **292,** 175–183.
- Graham, K., Beckerman, A.P. & Thirgood, S. (2005) Human-predator-prey conflicts: ecological correlates, prey losses and patterns of management. *Biological Conservation,* **122,** 159-171
- Groff, C., Angeli, F., Asson, D., Bragalanti, N., Pedrotti, L., Rizzoli, R. & Zanghellini, P. (2018) Rapporto Grandi carnivori 2017 *Servizio Foreste e fauna della Provincia Autonoma di Trento***,** 56.
- Gula, R. (2008) Wolf depredation on domestic animals in the Polish Carpathian mountains. *Journal of Wildlife Management,* **72,** 283-289.
- Hadjigeorgiou, I. (2011) Past, present and future of pastoralism in Greece. *Pastoralism,* **1**.
- Hall, S.J.G. & Bradley, D.G. (1995) Conserving livestock breed biodiversity. *Trends in Ecology and Evolution,* **10,** 267-270.
- Hawley, J.E., Gehring, T.M., Schultz, R.N., Rossler, S.T. & Wydeven, A.P. (2009) Assessment of shock collars as nonlethal management for wolves in Wisconsin. *Journal of Wildlife Management,* **73,** 518-525.
- Hazell, P. & Wood, S. (2008) Drivers of change in global agriculture. *Philosophical Transactions of the Royal Society B-Biological Sciences,* **363,** 495-515.
- Heikkinen, H.I., Moilanen, O., Nuttall, M. & Sarkki, S. (2011) Managing predators, managing reindeer: contested conceptions of predator policies in Finland's southeast reindeer herding area. *Polar Record,* **47,** 218-230.

- Helle, T.P. & Jaakkola, L.M. (2008) Transitions in herd management of semi-domesticated reindeer in northern Finland. *Annales Zoologici Fennici,* **45,** 81-101.
- Herfindal, I., Linnell, J.D.C., Moa, P.F., Odden, J., Austmo, L.B. & Andersen, R. (2005) Does recreational hunting of lynx reduce depredation losses of domestic sheep. *Journal of Wildlife Management,* **69,** 1034-1042.
- Hiedanpaa, J. (2013) Institutional Misfits: Law and Habits in Finnish Wolf Policy. *Ecology and Society,* **18**.
- Hinojosa, L., Lambin, E.F., Mzoughi, N. & Napoleone, C. (2018) Constraints to farming in the Mediterranean Alps: Reconciling environmental and agricultural policies. *Land Use Policy,* **75,** 726-733.
- Hobbs, N.T., Andren, H., Persson, J., Aronsson, M. & Chapron, G. (2012) Native predators reduce harvest of reindeer by Sami pastoralists. *Ecological Applications,* **22,** 1640-1654.
- Iason, G.R., Mantecon, A.R., Sim, D.A., Gonzalez, J., Foreman, E., Bermudez, F.F. & Elston, D.A. (1999) Can grazing sheep compensate for a daily foraging time constraint? *Journal of Animal Ecology,* **68,** 87-93.
- Imbert, C., Caniglia, R., Fabbri, E., Milanesi, P., Randi, E., Serafini, M., Torretta, E. & Meriggi, A. (2016) Why do wolves eat livestock? Factors influencing wolf diet in northern Italy. *Biological Conservation,* **195,** 156-168.
- Inskip, C. & Zimmermann, A. (2009) Human-felid conflict: a review of patterns and priorities worldwide. *Oryx,* **43,** 18-34.
- Jacobsen, K.S. & Linnell, J.D.C. (2016) Perceptions of environmental justice and the conflict surrounding large carnivore management in Norway - Implications for conflict management. *Biological Conservation,* **203,** 197-206.
- Jernsletten, J.L. & Klokov, K. (2003) *Sustainable reindeer herding.* Report to the Arctic Council, Tromsø, Norway.
- Kaartinen, S., Luoto, M. & Kojola, I. (2009) Carnivore-livestock conflicts: determinants of wolf (Canis lupus) depredation on sheep farms in Finland. *Biodiversity and Conservation,* **online early**.
- Kaczensky, P. & Huber, T. (1994) *Wer was es?* Institute für Wildbiologie und Jagdwirtschaft der Universität für Bodenkulur in Wien.
- Kaczensky, P. (1999) Large carnivore depredation on livestock in Europe. *Ursus,* **11,** 59-72.
- Kaczensky, P., Chapron, G., Von Arx, M., Huber, D., Andrén, H. & Linnell, J. (2013) *Status, management and distribution of large carnivores - bear, lynx, wolf and wolverine - in Europe*. Istituto di Ecologia Applicata, Rome, Italy.
- Karlsson, J. & Johansson, O. (2010) Predictability of repeated carnivore attacks on livestock favours reactive use of mitigation measures. *Journal of Applied Ecology,* **47,** 166-171.
- Kavcic, I., Adamic, M., Kaczensky, P., Krofel, M. & Jerina, K. (2013) Supplemental feeding with carrion is not reducing brown bear depredations on sheep in Slovenia. *Ursus,* **24,** 111-119.
- Kikvidze, Z. & Tevzadze, G. (2015) Loss of traditional knowledge aggravates wolf-human conflict in Georgia (Caucasus) in the wake of socio-economic change. *Ambio,* **44,** 452-457.
- Knarrum, V., Sørensen, O.J., Eggen, T., Kvam, T., Opseth, O., Overskaug, K. & Eidsmo, A. (2006) Brown bear predation on domestic sheep in central Norway. *Ursus,* **17,** 67-74.
- Kompaniyets, L. & Evans, M.A. (2017) Modeling the relationship between wolf control and cattle depredation. *Plos One,* **12**.
- Krange, O., Odden, J., Skogen, K., Linnell, J.D.C., Stokland, H.B., Vang, S. & Mattisson, J. (2016) Evaluering av regional rovviltforvaltning. *NINA Rapport,* **1268,** 1-190.

- Kruuk, H. (1972) Surplus killing by carnivores. *Journal of Zoology,* **166,** 233-244.
- Kuemmerle, T., Hostert, P., Radeloff, V.C., van der Linden, S., Perzanowski, K. & Kruhlov, I. (2008) Cross-border comparison of post-socialist farmland abandonment in the Carpathians. *Ecosystems,* **11,** 614-628.
- Lagos, L. & Barcena, F. (2018) Spatial variability in wolf diet and prey selection in Galicia (NW Spain). *Mammal Research,* **63,** 125-139.
- Landa, A., Krogstad, S., Tømmerås, B.Å. & Tufto, J. (1998) Do volatile repellents reduce wolverine Gulo gulo predation on sheep? - results of a large scale experiment. *Wildlife Biology,* **4,** 111-118.
- Lescureux, N. & Linnell, J.D.C. (2014) Warring brothers: the complex interactions between wolves (Canis lupus)) and dogs (Canis familiaris) in a conservation context. *Biological Conservation,* **171,** 232-245.
- Levin, M., Karlsson, J., Svensson, L., Hansers, M. & Ångsteg, I. (2008) *Besiktning av rovdjursangripna tamdjur*. Vildskadecenter.
- Linkowski, W.A., Kvarnstrom, M., Westin, A., Moen, J. & Ostlund, L. (2017) Wolf and Bear Depredation on Livestock in Northern Sweden 1827-2014: Combining History, Ecology and Interviews. *Land,* **6**.
- Linnell, J.D.C. & Boitani, L. (2012) Building biological realism into wolf management policy: the development of the population approach in Europe. *Hystrix - Italian Journal of Mammalogy,* **23,** 80-91.
- Linnell, J.D.C. & Lescureux, N. (2015) *Livestock guarding dogs - cultural heritage icons with a new relevance for mitigating conservation conflicts*. Norwegian Institute for Nature Research, Trondheim.
- Linnell, J.D.C. (2013) *From conflict to coexistence: insights from multi-disciplinary research into the relationships between people, large carnivores and institutions*. Istituto di Ecologia Applicata, Rome.
- Linnell, J.D.C. (2015) Defining scales for managing biodiversity and natural resources in the face of conflicts. In: Redpath S, Young J (Eds). . Cambridge, UK: Cambridge University Press. *Conflicts in conservation: navigating towards solutions* (eds S.M. Redpath, R.J. Guitiérrez, K.A. Wood & J.C. Young), pp. 208-218. Cambridge University Press, Cambridge.
- Linnell, J.D.C., Breitenmoser, U., Breitenmoser-Würsten, C., Odden, J. & von Arx, M. (2009) Recovery of Eurasian lynx in Europe: what part has reintroduction played? *Reintroduction of top-order predators* (eds M.W. Hayward & M.J. Somers), pp. 72-91. Wiley-Blackwell, Oxford.
- Linnell, J.D.C., Brøseth, H., Odden, J. & Nilsen, E.B. (2010) Sustainably harvesting a large carnivore? Development of Eurasian lynx populations in Norway during 160 years of shifting policy. *Environmental Management,* **45,** 1142-1154.
- Linnell, J.D.C., Brøseth, H., Solberg, E.J. & Brainerd, S. (2005) The origins of the southern Scandinavian wolf Canis lupus population: potential for natural immigration in relation to dispersal distances, geography and Baltic ice. *Wildlife Biology,* **11,** 383-391.
- Linnell, J.D.C., Nilsen, E.B., Lande, U.S., Herfindal, I., Odden, J., Skogen, K., Andersen, R. & Breitenmoser, U. (2005) Zoning as a means of mitigating conflicts with large carnivores: principles and reality. *People & Wildlife: conflict or co-existence* (eds R. Woodroffe, S. Thirgood & A. Rabinowitz), pp. 163-174. Cambridge University Press, Cambridge.
- Linnell, J.D.C., Odden, J., Smith, M.E., Aanes, R. & Swenson, J.E. (1999) Large carnivores that kill livestock: do "problem individuals" really exist? *Wildlife Society Bulletin,* **27,** 698-705.
- Linnell, J.D.C., Salvatori, V. & Boitani, L. (2008) *Guidelines for population level management plans for large carnivores in Europe.* A Large Carnivore Initiative for Europe report prepared for the European Commission (contract 070501/2005/424162/MAR/B2).

- Linnell, J.D.C., Smith, M.E., Odden, J., Kaczensky, P. & Swenson, J.E. (1996) Strategies for the reduction of carnivore - livestock conflicts: a review. *Norwegian Institute for Nature Research Oppdragsmelding,* **443,** 1-118.
- Linnell, J.D.C., Trouwborst, A. & Fleurke, F.M. (2017) When is it acceptable to kill a strictly protected carnivore? Exploring the legal constraints on wildlife management within Europe's Bern Convention. *Nature Conservation-Bulgaria***,** 129-157.
- Liukkonen, T., Mykrä, S., Bisi, J. & Kurki, S. (2009) Conflicts and compromises in lynx Lynx lynx conservation and management in Finland. *Wildlife Biology,* **15,** 165-174.
- Llaneza, L. & Lopez-Bao, J.V. (2015) Indirect effects of changes in environmental and agricultural policies on the diet of wolves. *European Journal of Wildlife Research,* **61,** 895-902.
- López-Bao, J.V., Sazatornil, V., Llaneza, L. & Rodríguez, A. (2013) Indirect effects on heathland conservation and wolf persistence of contradictory policies that threaten traditional free-ranging horse husbandry. *Conservation Letters,* **6,** 448-455.
- Lute, M.L., Carter, N.H., V., L.-B.J. & Linnell, J.D.C. (2018) Conservation professionals agree on challenges to coexisting with large carnivores but not on solutions. *Biological Conservation,* **218,** 223-232.
- Mabille, G., Stien, A., Tveraa, T., Mysterud, A., Broseth, H. & Linnell, J.D.C. (2015) Sheep farming and large carnivores: What are the factors influencing claimed losses? *Ecosphere,* **6,** Article 82.
- Mabille, G., Stien, A., Tveraa, T., Mysterud, A., Brøseth, H. & Linnell, J.D.C. (2016) Mortality and lamb body mass growth in free-ranging domestic sheep – environmental impacts including lethal and non-lethal impacts of predators. *Ecography,* **39,** 763-773.
- Maclennan, S.D., Groom, R.J., Macdonald, D.W. & Frank, L.G. (2009) Evaluation of a compensation scheme to bring about pastoralist tolerance of lions. *Biological Conservation,* **142,** 2419-2427.
- Marsden, K., Hovardas, T., Psaroudas, S., Mertzanis, Y. & Baatz, U. (2016) *EU Platform on large carnivores: supporting good practice for coexistence - presentation of examples and analysis of support through the EAFRD*. Adelphi Consult GmbH, Berlin.
- Marucco, F. & McIntire, E.J.B. (2010) Predicting spatio-temporal recolonization of large carnivore populations and livestock depredation risk: wolves in the Italian Alps. *Journal of Applied Ecology,* **47,** 789-798.
- Mattiello, S., Bresciani, T., Gaggero, S., Russo, C. & Mazzarone, V. (2012) Sheep predation: Characteristics and risk factors. *Small Ruminant Research,* **105,** 315-320.
- Mattisson, J., Arntsen, G.B., Nilsen, E.B., Loe, L.E., Linnell, J.D.C., Odden, J., Persson, J. & Andren, H. (2014) Lynx predation on semi-domestic reindeer: do age and sex matter? *Journal of Zoology,* **292,** 56-63.
- Mattisson, J., Odden, J. & Linnell, J.D.C. (2014) A catch-22 conflict: access to semi-domestic reindeer modulates Eurasian lynx depredation on domestic sheep. *Biological Conservation,* **179,** 116-122.
- Mattisson, J., Odden, J., Nilsen, E.B., Linnell, J.D.C., Persson, J. & Andren, H. (2011) Factors affecting Eurasian lynx kill rates on semi-domestic reindeer in northern Scandinavia: Can ecological research contribute to the development of a fair compensation system? *Biological Conservation,* **144,** 3009-3017.
- Mattisson, J., Odden, J., Strømseth, T.H., Rauset, G.R., Flagstad, Ø. & Linnell, J.D.C. (2015) Gaupe og jerv i reinbeiteland: sluttrapport for Scandlynx Troms og Finnmark 2007 - 2014. *NINA Rapport,* **1200,** 1-50.

- May, R., van Dijk, J., Forland, J.M., Andersen, R. & Landa, A. (2008) Behavioural patterns in ewe-lamb pairs and vulnerability to predation by wolverines. *Applied Animal Behaviour Science,* **112,** 58-67.
- Meriggi, A. & Lovari, S. (1996) A review of wolf predation in southern Europe: does the wolf prefer wild prey to livestock? *Journal of Applied Ecology,* **33,** 1561-1571.
- Mertens, A. & Promberger, C. (2001) Economic aspects of large carnivore-livestock conflicts in Romania. *Ursus,* **12,** 173-180.
- Mertens, A., Promberger, C. & Gheorghe, P. (2002) Testing and implementing the use of electric fences for night corrals in Romania. *Carnivore Damage Prevention News,* **5,** 2-4.
- Milanesi, P., Breiner, F.T., Puopolo, F. & Holderegger, R. (2017) European human-dominated landscapes provide ample space for the recolonization of large carnivore populations under future land change scenarios. *Ecography,* **40,** 1359-1368.
- Milheiras, S. & Hodge, I. (2011) Attitudes towards compensation for wolf damage to livestock in Viana do Castelo, North of Portugal. *Innovation-the European Journal of Social Science Research,* **24,** 333-351.
- Moa, P.F., Herfindal, I., Linnell, J.D.C., Overskaug, K., Kvam, T. & Andersen, R. (2006) Does the spatiotemporal distribution of livestock influence forage patch selection in Eurasian lynx Lynx lynx? *Wildlife Biology,* **12,** 63-70.
- Molinari, P., Breitenmoser, U., Molinari-Jobin, A. & Giacometti, M. (2000) *Les prédateurs en action: manuel sur l'identification des proies de grands prédateurs et d'autres signes de présence*. Wildvet Projects.
- Musiani, M. & Visalberghi, E. (2001) Effectiveness of fladry on wolves in captivity. *Wildlife Society Bulletin,* **29,** 91-98.
- Muuttoranta, K. & Maki-Tanila, A. (2012) Regional differences in reindeer herding operations in Finland. *Acta Agriculturae Scandinavica Section a-Animal Science,* **62,** 142-152.
- Naess, M.W., Bårdsen, B.J. & Tveraa, T. (2012) Wealth-dependent and interdependent strategies in the Saami reindeer husbandry, Norway. *Evolution and Human Behavior,* **33,** 696-707.
- Naess, M.W., Bardsen, B.J., Pedersen, E. & Tveraa, T. (2011) Pastoral herding strategies and governmental management objectives: predation compensation as a risk buffering strategy in the Saami reindeer husbandry. *Human Ecology,* **39,** 489-508.
- Naughton-Treves, L., Grossberg, R. & Treves, A. (2003) Paying for tolerance: rural citizens' attitudes toward wolf depredation and compensation. *Conservation Biology,* **17,** 1500-1511.
- Newsome, T.M., Boitani, L., Chapron, G., Ciucci, P., Dickman, C.R., Dellinger, J.A., Lopez-Bao, J.V., Peterson, R.O., Shores, C.R., Wirsing, A.J. & Ripple, W.J. (2016) Food habits of the world's grey wolves. *Mammal Review,* **46,** 255-269.
- Nieminen, M. & Leppäluoto, J. (1988) Predation in the reindeer husbandry area in Finland during 1976-1986. *Rangifer,* **8,** 25-34.
- Nieminen, M., Norberg, H. & Maijala, V. (2011) Mortality and survival of semi-domesticated reindeer (Rangifer tarandus L.) calves in northern Finland. *Rangifer,* **31,** 71-84.
- Nilsen, E.B., Broseth, H., Odden, J. & Linnell, J.D.C. (2012) Quota hunting of Eurasian lynx in Norway: patterns of hunter selection, hunter efficiency and monitoring accuracy. *European Journal of Wildlife Research,* **58,** 325-333.
- Nybakk, K., Kjelvik, O., Kvam, T., Overskaug, K. & Sunde, P. (2002) Mortality of semi-domestic reindeer Rangifer tarandus in central Norway. *Wildlife Biology,* **8,** 63-68.
- Nyhus, P.J., Osofsky, S.A., Ferraro, P., Madden, F. & Fischer, H. (2005) Bearing the costs of human-wildlife conflict: the challenges of compensation schemes. *People & Wildlife: conflict or co-*

existence (eds R. Woodroffe, S. Thirgood & A. Rabinowitz), pp. 107-121. Cambridge University Press, Cambridge.

- Odden, J., Herfindal, I., Linnell, J.D.C. & Andersen, R. (2008) Vulnerability of domestic sheep to lynx depredation in relation to roe deer density. *Journal of Wildlife Management,* **72,** 276-282.
- Odden, J., Linnell, J.D.C., Moa, P.F., Herfindal, I., Kvam, T. & Andersen, R. (2002) Lynx depredation on domestic sheep in Norway. *Journal of Wildlife Management,* **66,** 98-105.
- Odden, J., Mattisson, J., Gervasi, V. & Linnell, J. (2014) Gaupas predasjon på sau - en kunnskapsoversikt. *Norwegian Institute for Nature Research Temahefte,* **57**.
- Odden, J., Nilsen, E.B. & Linnell, J.D.C. (2013) Density of Wild Prey Modulates Lynx Kill Rates on Free-Ranging Domestic Sheep. *Plos One,* **8**.
- Ogada, M.O., Woodroffe, R., Oguge, N.O. & Frank, L.G. (2003) Limiting depredation by African carnivores: the role of livestock husbandry. *Conservation Biology,* **17,** 1521-1530.
- Olson, L. (2002) Habitat effects on diet and reproduction of female wolverines. MSc Thesis, Biology Institute, NTNU, Norway.
- Ostavel, T., Vuori, K.A., Sims, D.E., Valros, A., Vainio, O. & Saloniemi, H. (2009) The first experience of livestock guarding dogs preventing large carnivore damages in Finland. *Estonian Journal of Ecology,* **58,** 216-224.
- Pedersen, V., Linnell, J.D.C., Andersen, R., Andrén, H., Segerström, P. & Lindén, M. (1999) Winter lynx predation on semi-domestic reindeer in northern Sweden. *Wildlife Biology,* **5,** 203-212.
- Persson, J., Rauset, G.R. & Chapron, G. (2015) Paying for an Endangered Predator Leads to Population Recovery. *Conservation Letters,* **8,** 345-350.
- Pimenta, V., Barroso, I., Boitani, L. & Beja, P. (2017) Wolf predation on cattle in Portugal: Assessing the effects of husbandry systems. *Biological Conservation,* **207,** 17-26.
- Potgieter, G.C., Kerley, G.I.H. & Marker, L.L. (2016) More bark than bite? The role of livestock guarding dogs in predator control on Namibian farmlands. *Oryx,* **50,** 514-522.
- Ravenelle, J. & Nyhus, P.J. (2017) Global patterns and trends in human-wildlife conflict compensation. *Conservation Biology,* **31,** 1247-1256.
- Razen, N., Brugnoli, A., Castagna, C., Groff, C., Kaczensky, P., Kljun, F., Knauer, F., Kos, I., Krofel, M., Lustrik, R., Majic, A., Rauer, G., Righetti, D. & Potocnik, H. (2016) Long-distance dispersal connects Dinaric-Balkan and Alpine grey wolf (Canis lupus) populations. *European Journal of Wildlife Research,* **62,** 137-142.
- Rigg, R. (2001) *Livestock guarding dogs: their current use world wide*. IUCN / SSC Canid Specialist Group Occasional Paper No.1 [online], URL: http://www.canids.org/occasionalpapers/.
- Rigg, R., Findo, S., Wechselberger, M., Gorman, M.L., Sillero-Zubiri, C. & Macdonald, D.W. (2011) Mitigating carnivore-livestock conflict in Europe: lessones from Slovaka. *Oryx,* **45,** 272-280.
- Rivrud, I.M., Sivertsen, T.R., Mysterud, A., Ahman, B., Stoen, O.G. & Skarin, A. (2018) Reindeer green-wave surfing constrained by predators. *Ecosphere,* **9**.
- Rondinini, C. & Boitani, L. (2007) Systematic conservation planning and the cost of tackling conservation conflicts with large carnivores in Iyaly. *Conservation Biology,* **21,** 1455-1462.
- Rook, A.J., Dumont, B., Isselstein, J., Osoro, K., Wallis De Vries, M.F., Parente, G. & Mills, J. (2004) Matching type of livestock to desired biodiversity outcomes in pastures -a review. *Biological Conservation*.
- Rosen, T. & Bath, A. (2009) Transboundary management of large carnivores in Europe: from incident to opportunity. *Conservation Letters,* **2,** 109-114.
- Sagør, J.T., Swenson, J.E. & Røskaft, E. (1997) Compatibiity of brown bear Ursus arctos and free-ranging sheep in Norway. *Biological Conservation,* **81,** 91-95.

- Salvatori, V. (2012) *Large carnivore conservation and management in Europe: the contribution of EC co-funded LIFE projects*. Isttituto di Ecologia Applicata, Rome, Italy.
- Santiago-Avila, F.J., Cornman, A.M. & Treves, A. (2018) Killing wolves to prevent predation on livestock may protect one farm but harm neighbors. *Plos One,* **13**.
- Scasta, J.D., Stam, B. & Windh, J.L. (2017) Rancher-reported efficacy of lethal and non-lethal livestock predation mitigation strategies for a suite of carnivores. *Scientific Reports,* **7**.
- Schwerdtner, K. & Gruberb, B. (2007) A conceptual framework for damage compensation schemes. *Biological Conservation,* **134,** 354 –360.
- Sendyka, P. & Makovicky, N. (2018) Transhumant pastoralism in Poland: Contemporary challenges. *Pastoralism,* **8**.
- Shivik, J. (2006) Tools for the edge: what's new for conserving carnivores. *BioScience,* **56,** 253-259.
- Shivik, J.A., Treves, A. & Callahan, P. (2003) Nonlethal techniques for managing predation: Primary and secondary repellents. *Conservation Biology,* **17,** 1531-1537.
- Sidorovich, V.E., Tikhomirova, L.L. & Jedrzejewska, B. (2003) Wolf Canis lupus numbers, diet and damage to livestock in relation to hunting and ungulate abundance in northeastern Belarus during 1990-2000. *Wildlife Biology,* **9,** 103-112.
- Silva, J.P., Toland, J., Hudson, T., Jones, W., Eldridge, J., Thorpe, E., Bacchereti, S., Nottingham, S., Thévignot, C. & Demeter, A. (2013) *LIFE and human coexistence with large carnivores*. European Commission DG Environment.
- Sivertsen, T.R., Ahman, B., Steyaert, S., Ronnegard, L., Frank, J., Segerstrom, P., Stoen, O.G. & Skarin, A. (2016) Reindeer habitat selection under the risk of brown bear predation during calving season. *Ecosphere,* **7**.
- Sjolander-Lindqvist, A. (2015) Targeted removal of wolves: analysis of the motives for controlled hunting. *Wildlife Biology,* **21,** 138-146.
- Skogen, K. (2015) The Persistence of an Economic Paradigm: Unintended Consequences in Norwegian Wolf Management. *Human Dimensions of Wildlife,* **20,** 317-322.
- Skogen, K., Krange, O. & Figari, H. (2017) *Wolf conflicts: a sociological study*. Berghahn Books, Oxford.
- Skogen, K., Mauz, I. & Krange, O. (2008) Cry wolf! Narratives of wolf recovery in France and Norway. *Rural Sociology,* **73,** 105-133.
- Skonhoft, A. (2017) The Silence of the Lambs: Payment for Carnivore Conservation and Livestock Farming Under Strategic Behavior. *Environmental & Resource Economics,* **67,** 905-923.
- Skonhoft, A., Johannesen, A.B. & Olaussen, J.O. (2017) On the tragedy of the commons: When predation and livestock loss may improve the economic lot of herders. *Ambio,* **46,** 644-654.
- Smith, M.E., Linnell, J.D.C., Odden, J. & Swenson, J.E. (2000) Review of methods to reduce livestock depredation II. Aversive conditioning, deterrents and repellents. *Acta Agriculturae Scandinavica Section a-Animal Science,* **50,** 304-315.
- Smith, M.E., Linnell, J.D.C., Odden, J. & Swenson, J.E. (2000) Review of methods to reduce livestock depredation: I. Guardian animals. *Acta Agriculturae Scandinavica Section a-Animal Science,* **50,** 279-290.
- Stahl, P. & Vandel, J.M. (2001) Factors influencing lynx depredation on sheep in France: problem individuals and habitat. *Carnivore Damage Prevention News,* **4,** 6-7.
- Stahl, P., Vandel, J.M., Herrenschmidt, V. & Migot, P. (2001) The effect of removing lynx in reducing attacks in sheep in the French Jura mountains. *Biological Conservation,* **101,** 15-22.

- Stoynov, E., Grozdanov, A., Stanchev, S., Peshev, H., CVangelova, N. & Peshev, D. (2014) How to avoid depredation on livestock by wolf - theories and tests. *Bulgarian Journal of Agricultural Science,* **20**.
- Sundqvist, A.K., Ellegren, H. & Vilà, C. (2008) Wolf or dog? Genetic identification of predators from saliva collected around bite wounds on prey. *Conservation Genetics,* **9,** 1275-1279.
- Svensson, L., Ahlqvist, I. & Kjellander, P. (1998) *Electric fencing to prevent bear damage on beehives [Elstängsel som förebyggande åtgärd mot bjärnskador på bikupor]*. Viltskade center, Grimsö Forskningsstation.
- Swenson, J.E. & Andrén, H. (2005) A tale of two countries: large carnivore depredation and compensation schemes in Sweden and Norway. *People and wildlife: conflict or coexistence?* (eds R. Woodroffe, S. Thirgood & A. Rabinowitz), pp. 323-339. Cambridge University Press, Cambridge.
- Torres, R.T., Silva, N., Brotas, G. & Fonseca, C. (2015) To Eat or Not To Eat? The Diet of the Endangered Iberian Wolf (Canis lupus signatus) in a Human- Dominated Landscape in Central Portugal. *Plos One,* **10**.
- Treves, A. & Naughton-Treves, L. (2005) Evaluating lethal control in the management of human-wildlife conflict. *People and wildlife: conflict or coexistence?* (eds R. Woodroffe, S. Thirgood & A. Rabinowitz), pp. 86-106. Cambridge University Press, Cambridge.
- Treves, A. (2009) Hunting for large carnivore conservation. *Journal of Applied Ecology,* **46,** 1350-1356.
- Treves, A., Krofel, M. & McManus, J. (2016) Predator control should not be a shot in the dark. *Frontiers in Ecology and the Environment,* **14,** 380-388.
- Treves, A., Naughton-Treves, L., Harper, E.K., Mladenoff, D.J., Rose, R.A., Sickley, T.A. & Wydeven, A.P. (2004) Predicting carnivore-human conflict: a spatial model derived from 25 years of data on wolf predation on livestock. *Conservation Biology,* **18,** 114-125.
- Trouwborst, A. (2010) Managing the Carnivore Comeback: International and EU Species Protection Law and the Return of Lynx, Wolf and Bear to Western Europe. *Journal of Environmental Law,* **22,** 347-372.
- Trouwborst, A. (2014) The EU Habitats Directive and wolf conservation and management on the Iberian Peninsula: a legal perspective. *Galemys,* **26,** 15-30.
- Trouwborst, A. (2018) Wolves not welcome? Zoning for large carnivore conservation and management under the Bern Convention and EU Habitats Directive. *Review of European, Comparative and International Environmental Law,* **in press**.
- Trouwborst, A., Boitani, L. & Linnell, J.D.C. (2017) Interpreting 'favourable conservation status' for large carnivores in Europe: how many are needed and how many are wanted? *Biodiversity and Conservation,* **26,** 37-61.
- Trouwborst, A., Fleurke, F. & Linnell, J.D.C. (2017) Norway's Wolf Policy and the Bern Convention on European Wildlife: Avoiding the "Manifestly Absurd". *Journal of International Wildlife Law & Policy,* **in press**.
- Trouwborst, A., Krofel, M. & Linnell, J.D.C. (2015) Legal implications of range expansions in a terrestrial carnivore: the case of the golden jackal (Canis aureus) in Europe. *Biodiversity and Conservation,* **24,** 2593-2610.
- Tveraa, T., Ballesteros, M., Bårdsen, B.J., Fauchald, P., Lagergren, M., Langeland, K., Pedersen, E. & Stien, A. (2012) Rovvilt og reindrift: kunnskapstatus i Finnmark. *NINA Rapport,* **821,** 1-28.
- Tveraa, T., Fauchald, P., Henaug, C. & Yoccoz, N.G. (2003) An examination of a compensatory relationship between food limitation and predation in semi-domestic reindeer. *Oecologia,* **137,** 370-376.

- Tveraa, T., Fauchald, P., Yoccoz, N., Ims, R.A., Aanes, R. & Høgda, K.A. (2007) What regulates and limits reindeer populations in Norway. *Oikos,* **116,** 706-715.
- Tveraa, T., Stien, A., Broseth, H. & Yoccoz, N.G. (2014) The role of predation and food limitation on claims for compensation, reindeer demography and population dynamics. *Journal of Applied Ecology,* **51,** 1264-1272.
- Tveraa, T., Stien, A., Odden, J. & Linnell, J.D.C. (2014) Rovdyr - reindriftas viktigste tapsårsak? *Norsk Veterinærtidsskrift,* **126,** 104-111.
- van Liere, D., Dwyer, C., Jordan, D., Premik-Banic, A., Valencic, A., Kompan, D. & Siard, N. (2013) Farm characteristics in Slovene wolf habitat related to attacks on sheep. *Applied Animal Behaviour Science,* **144,** 46-56.
- van Vliet, J., de Groot, H.L.F., Rietveld, P. & Verburg, P.H. (2015) Manifestations and underlying drivers of agricultural land use change in Europe. *Landscape and Urban Planning,* **133,** 24-36.
- Wam, H., Dokk, J.G. & Hjeljord, O. (2003) *Electric fencing and large carnivore depredation on livestock in Østfold [Tilskuddsgjerder og rovdyrskader på bufe i Østfold].* Institutt for biologi og naturforvaltning Viltrapport 4, Norges Landbruks Høgskole.
- Wang, S.W. & Macdonald, D.W. (2006) Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. *Biological Conservation,* **129,** 558-565.
- Warren, J.J. & Mysterud, I. (2001) Mortality of lambs in free-ranging domestic sheep (Ovis aries) in northern Norway. *Journal of Zoology, London,* **254,** 195-202.
- Wielgus, R.B. & Peebles, K.A. (2014) Effects of Wolf Mortality on Livestock Depredations. *Plos One,* **9**.
- Zabel, A. & Holm-Müller, K. (2008) Conservation performance payments for carnivore conservation in Sweden. *Conservation Biology,* **22,** 247–251.
- Zabel, A., Bostedt, G. & Engel, S. (2014) Performance Payments for Groups: The Case of Carnivore Conservation in Northern Sweden. *Environmental & Resource Economics,* **59,** 613-631.
- Zimmermann, B., Wabakken, P. & Dötterer, M. (2003) Brown bear-livestock conflicts in a bear conservation zone in Norway: are cattle a good alternative to sheep? *Ursus,* **14,** 72-83.
- Zingaro, M. & Boitani, L. (2017) Assessing wild canid depredation risk using a new three steps method: the case of Grosseto province (Tuscany, Italy). *Hystrix-Italian Journal of Mammalogy,* **28**.
- Zlatanova, D., Ahmed, A., Valasseva, A. & Genov, P. (2014) Adaptive Diet Strategy of the Wolf (Canis lupus L.) in Europe: a Review. *Acta Zoologica Bulgarica,* **66,** 439-452.

ANNEX 1 CONTACTS WHO PROVIDED DATA

National contacts who provided data on carnivore distribution and numbers and compensation payments.

Wolves

Country	Population	Compiler	Affiliation
Albania	Balkan	Aleksandër Trajçe, Bledi Hoxha	Protection and Preservation of Natural Environment in Albania
Bosnia	Dinaric	Igor Trbojević	University of Banja Luka, Faculty of Science
Bulgaria	Dinaric	Elena Tsingarska	Balkani Wildlife Society
Croatia	Dinaric-Balkan	Josip Kusak[1], Jasna Jeremić[2]	[1]University of Zagreb, Department of Biology; [2]State Institute for Nature Protection, Department for Wild and Domesticated Taxa and Habitats
Czech Republic	Carpathian	Miroslav Kutal[1,2]	[1]Friends of the Earth Czech Republic, [2]Department of Forest Ecology, Faculty of Forestry and Wood technology, Mendel University Brno, Czech Republic
Czech Republic	Central European Lowland	Miroslav Kutal[1,2]	[1]Friends of the Earth Czech Republic, [2]Department of Forest Ecology, Faculty of Forestry and Wood technology, Mendel University Brno, Czech Republic
Denmark	Central European Lowland	Peter Sunde[1], Kent Olsen[2]	[1]Aarhus University, Department of Bioscience; [2]Natural History Museum, Danish Agency for the Environment
Estonia	Baltic	Peep Männil, Rauno Veeroja, Toñu Talvi	Estonian Environment Agency, Department of Wildlife Monitoring
Finland	Karelian	Ilpo Kojola and Harri Norberg	Natural Resources Institute Finland
France	Alps	C. Duchamp & M. Metral	Office national de la chasse et de la faune sauvage ONCFS, Réseau Loup-Lynx
Germany	Central European Lowland	Ilka Reinhardt[1,2]	[1]LUPUS German Institute for Wolf Monitoring and Research; [2]Dokumentations- und Beratungsstelle des Bundes zum Thema Wolf (DBBW); Federal Agency for Nature Conservation (BfN); federal states of Germany
Greece	Continental Greek Population	Iliopoulos Yorgos	Callisto Wildlife Society
Italy	Alps	Francesca Marucco	Progetto LIFE WolfAlps, Centro Grandi Carnivori, Ente di Gestione delle Aree Protette delle Alpi Marittime
Italy	Appennines	Valeria Salvatori, Federal regions	Istituto di Ecologia Applicata

Kosovo	South	Azem Ramadani, Rafet Elezi	Environmentally Responsible Action (ERA), Balkan Lynx Recovery Programme
Kosovo	West	Azem Ramadani, Rafet Elezi	Environmentally Responsible Action (ERA), Balkan Lynx Recovery Programme
Latvia	Baltic	Jānis Ozoliņš	Latvian State Forest Research Institute "Silava"
Lithuania	Baltic	Vaidas Balys	Association for Nature Conservation "Baltijos vilkas";
Luxembourg	Central European Lowland	Dr. Laurent Schley	Administration de la nature et des forêts · Direction
Macedonia	Dinaric-Balkan	Dime Melovski	Macedonian Ecological Society | MES · Department of Wildlife Sciences, University of Goettingen
Netherlands	West-European lowland population	Leo Linnartz[1,2], Glenn Lelieveld[1,3]	[1]Wolven in Nederland; [2]ARK Natuurontwikkeling; [3]Dutch Mammal Society;
Norway	Scandinavian	John Linnell, John Odden, Henrik Brøseth	Norwegian Institute for Nature Research
Poland	Baltic	Sabina Nowak[1], Robert Mysłajek[2]	[1]Association for Nature "Wolf"; [2]University of Warsaw, Faculty of Biology, Institute of Genetics and Biotechnology
Poland	Carpathian	Sabina Nowak[1], Robert Mysłajek[2]	[1]Association for Nature "Wolf"; [2]University of Warsaw, Faculty of Biology, Institute of Genetics and Biotechnology
Poland	Central European	Sabina Nowak[1], Robert Mysłajek[2]	[1]Association for Nature "Wolf"; [2]University of Warsaw, Faculty of Biology, Institute of Genetics and Biotechnology
Portugal	North-West Iberia	Francisco Álvares[1], Mónia Nakamura[1], Virginia Pimenta[1], Inês Barroso[2]	[1]CIBIO, Research Center in Biodiversity and Genetic Resources, Porto University; [2]ICNF, Institute for Nature Conservation and Forests
Serbia	Carpathian	Duško Ćirović	University of Belgrade, Faculty of Biology
Serbia	Dinaric	Duško Ćirović	University of Belgrade, Faculty of Biology
Slovakia	Carpathian	Robin Rigg,	Slovak Wildlife Society
Slovenia	Dinaric-Balkan	Hubert Potočnik	University of Ljubljana, Faculty of Biotechnology
Spain	North-West Iberia	Juan Carlos Blanco	Wolf Project, Consultores en Biología de la Conservación
Spain	Sierra Morena	Juan Carlos Blanco	Wolf Project, Consultores en Biología de la Conservación
Sweden	Scandinavian	Henrik Andrén	Swedish University of Agricultural Sciences

Switzerland	Alps	Manuela von Arx, Ralph Manz, Florin Kunz, Fridolin Zimmermann	Carnivore Ecology and Wildlife Management - KORA
Ukraine	Carpathian	M. Shkvyria	Kyiv Zoological Park of National importance
Ukraine	Lowland	M. Shkvyria	Kyiv Zoological Park of National importance
Italy	Alps	Francesca Marucco	Progetto LIFE WolfAlps, Centro Grandi Carnivori, Ente di Gestione delle Aree Protette delle Alpi Marittime

Bears

Country	Population	Compiler	Affiliation
Albania	Dinaric-Pindos	Aleksandër Trajçe, Bledi Hoxha	Society for the Protection and Preservation of Natural Environment in Albania - PPNEA
Bosnia	Dinaric-Pindos	Igor Trbojević	University of Banja Luka, Faculty of Science
Catalonia, Spain, France	Pyrenean	Santiago Palazon	Fauna and Flora Service, Ministry of Territory and Sustainability
Croatia	Dinaric-Pindos	Slaven Reljić, Djuro Huber	University of Zagreb, Department of Biology
Czech Republic	Carpathian	Miroslav Kutal [1,2]	[1]Friends of the Earth Czech Republic; [2]Department of Forest Ecology, Faculty of Forestry and Wood technology, Mendel University Brno
Estonia	Baltic	Peep Männil, Rauno Veeroja, Toñu Talvi	Estonian Environment Agency, Department of Wildlife Monitoring
Finland	Karelian	Ilpo Kojola and Harri Norberg	Natural Resources Institute Finland (Luke)
France, Spain, Andorra	Pyrenean	Cécile Vanpé and Jérôme Sentilles, Laurence Tribolet and Nicolas Gillodes	Office national de la chasse et de la faune sauvage ONCFS, Equipe Ours
France, Spain	Pyrenean	Santiago Palazon	Generalitat de Catalunya - Fauna and Flora Service
Greece	Dinaric-Pindos	Yorgos Merztanis	Callisto Wildlife and Nature Conservation Society
Greece	East Balkan – Greek Rodopi	Yorgos Merztanis	Callisto Wildlife and Nature Conservation Society
Hungary	Carpathian	Miklós Heltai, Sándor Csányi	Szent István University, Godollo
Italy	Appennines	Paolo Ciucci	Dipartimento di Biologia e Biotecnologie, Università di Roma "La Sapienza"

Italy	Central Alps	Claudio Groff	Provincia Autonoma di Trento, Forest and Wildlife Service
Latvia	Baltic	Jānis Ozoliņš	Latvian State Forest Research Institute "Silava"
Macedonia	Dinaric-Pindos	Dime Melovski	Macedonian Ecological Society - MES, Balkan Lynx Recovery Programme
Montenegro	Dinaric-Pindos	Aleksandar Perovic	Centre for protection and research of birds of Montenegro - CZIP
Norway	Karelian	Jon Swenson[1], Jonas Kindberg[2]	[1]Norwegian University of Life Sciences, [2]Swedish University of Agricultural Sciences
Norway	Scandinavian	Jon Swenson[1], Jonas Kindberg[2]	[1]Norwegian University of Life Sciences, [2]Swedish University of Agricultural Sciences
Serbia	Carpathian	Duško Ćirović	University of Belgrade, Faculty of Biology
Serbia	Dinaric-Pindos	Duško Ćirović	University of Belgrade, Faculty of Biology
Serbia	Eastern Balkan	Duško Ćirović	University of Belgrade, Faculty of Biology
Slovakia	Carpathian	Robin Rigg, Slovak Wildlife Society	Slovak Wildlife Society
Slovenia	Alpine-Dinaric-Pindos	Klemen Jerina, Miha Krofel, Tomaž Skrbinšek	University of Ljubljana, faculty of Biotechnology
Kosovo	South	Azem Ramadani & Rafet Elezi	Environmentally Responsible Action (ERA), Balkan Lynx Recovery Programme
Kosovo	West	Bardh Sanaja	Environmentally Responsible Action (ERA), Balkan Lynx Recovery Programme
Spain	Cantabrian	Juan Carlos Blanco, Guillermo Palomero, Fernando Ballesteros	Consultores en Biología de la Conservación
Sweden	Scandinavian	Jon Swenson[1], Jonas Kindberg[2]	[1]Norwegian University of Life Sciences, [2]Swedish University of Agricultural Sciences
Switzerland	Alps	Manuela von Arx, Andreas Ryser, Fridolin Zimmermann	Carnivore Ecology and Wildlife Management - KORA
Ukraine	Carpathian	Maryna Shkvyria	Kyiv Zoological Park of National importance

Lynx

Country	Population	Compiler	Affiliation
Albania	Balkan	Aleksandër Trajçe, Bledi Hoxha	Protection and Preservation of Natural Environment in Albania
Bosnia	Dinaric	Igor Trbojević[1], Tijana Trbojević[2]	[1]University of Banja Luka, Faculty of Science; [2]Ecology Research Association (EID)
Bulgaria	Carpathian	Diana Zlatanova	Department of Zoology and Anthropology, Faculty of Biology, Sofia University
Croatia	Dinaric	Djuro Huber, Josip Kusak, Slaven Reljić	University of Zagreb, Department of Biology
Czech Republic	Bohemian – Bavarian – Austrian population	Josefa Volfová, Elisa Belotti & Miroslav Kutal	[1]Friends of the Earth Czech Republic; [2]Administration of the National Park and Protective Landscape Area of Šumava;
Czech Republic	Carpathian	Miroslav Kutal[1,2]	[1]Friends of the Earth Czech Republic; [2]Department of Forest Ecology, Faculty of Forestry and Wood technology, Mendel University Brno;
Finland	Finnish	Katja Holmala	Natural Resources Institute Finland (Luke)
France	Alps	C. Duchamp, M. Metral	Office national de la chasse et de la faune sauvage ONCFS, Réseau Loup-Lynx
France	Jura	C. Duchamp	Office national de la chasse et de la faune sauvage ONCFS, Réseau Loup-Lynx
France	Vosges	C. Duchamp	Office national de la chasse et de la faune sauvage ONCFS, Réseau Loup-Lynx
Germany	Bavarian	Sybille Wölfl	Lynx Project Bavaria
Hungary	Carpathian	Miklós Heltai & Sándor Csányi	Szent István University, Godollo
Italy	Alps	Anja Molinari-Jobin	Status and Conservation of the Alpine Lynx Population - SCALP
Kosovo	Balkan	Azem Ramadani & Rafet Elezi	Environmentally Responsible Action (ERA), Balkan Lynx Recovery Programme
Kosovo	Balkan	Bardh Sanaja	Environmentally Responsible Action (ERA), Balkan Lynx Recovery Programme
Latvia	Baltic	Guna Bagrade	Latvian State Forest Research Institute “Silava”
Lithuania	Baltic	Vaidas Balys	Association for Nature Conservation “Baltijos vilkas”; Ministry of Agriculture (raw data)
Luxembourg	na	Dr. Laurent Schley	Administration de la nature et des forêts

Macedonia	Balkan	Dime Melovski	Macedonian Ecological Society
Norway	Scandinavian	John Linnell, John Odden, Henrik Brøseth	Norwegian Institute for Nature Research
Poland	Baltic	Sabina Nowak[1], Robert Mysłaje[2]	[1]Association for Nature "Wolf"; [2]University of Warsaw, Faculty of Biology, Institute of Genetics and Biotechnology
Poland	Carpathian	Sabina Nowak[1], Robert Mysłaje[2]	[1]Association for Nature "Wolf"; [2]University of Warsaw, Faculty of Biology, Institute of Genetics and Biotechnology
Serbia	Carpathian	Duško Ćirović	University of Belgrade, Faculty of Biology
Slovakia	Carpathian	Robin Rigg, Slovak Wildlife Society (SWS)	Slovak Wildlife Society
Slovenia	Whole country	Nives Pagon, Matej Bartol, Rok Černe	University of Belgrade, Faculty of Biology
Sweden	Scandinavian	Henrik Andrén	Swedish University of Agricultural Sciences, Department of Ecology
Switzerland	Alps	Fridolin Zimmermann, Florin Kunz, Manuela von Arx	Carnivore Ecology and Wildlife Management - KORA
Switzerland	Jura	Fridolin Zimmermann, Florin Kunz, Manuela von Arx	Carnivore Ecology and Wildlife Management - KORA
Ukraine	Carpathian	Maryna Shkvyria	Kyiv Zoological Park of National importance
Ukraine	Lowland	Maryna Shkvyria	Kyiv Zoological Park of National importance

Wolverines

Country	Population	Compiler	Affiliation
Finland	Scandinavian, Karelian	Ilpo Kojola and Harri Norberg	Natural Resources Institute Finland (Luke)
Norway	Scandinavian	John Linnell, John Odden, Henrik Brøseth	Norwegian Institute for Nature Research
Sweden	Scandinavian	Henrik Andrén	Swedish University of Agricultural Sciences,Department of Ecology

ANNEX 2 LIVESTOCK DATA SOURCES

Data sources for sheep numbers in European countries

Type of data	Source	Link
Sheep population - annual data [apro_mt_lssheep]	Eurostat	http://ec.europa.eu/eurostat
Animal populations by NUTS 2 regions [agr_r_animal]	Eurostat	http://ec.europa.eu/eurostat
Sheep population in Czech Republic (whole countryand by NUTS 2)	Czech Statistical Office	https://www.czso.cz
Sheep population in Denmark (whole country and by NUTS 2)	Statbank Denmark	https://www.statbank.dk
Sheep population in Estonia (whole country and by NUTS 2)	Estonian Statistics	https://www.stat.ee/en/
Sheep population in Ireland (whole country and by NUTS 2)	Central Statistics Office	http://www.cso.ie/en/index.html
Sheep population in Poland (whole country and by NUTS 2)	Statistics Poland	https://stat.gov.pl/en/
Sheep population in Slovenia (whole country and by NUTS 2)	Statistical Office	http://pxweb.stat.si/
Sheep population in Finland (whole country and by NUTS 2)	Statistics Finland	http://statdb.luke.fi/
Sheep population in Sweden (whole country and by NUTS 2)	Statistics Sweden	https://www.scb.se/
Sheep population in Switzerland (whole country and by canton)	Federal Statistics Office	https://www.bfs.admin.ch/bfs/en/home.html
Sheep population in Norway (whole country and by county)	Statistisk sentralbyrå	https://www.ssb.no

Sources of data on livestock numbers in Europe

Type of data	Source	Link
Sheep population in Europe	Eurostat	http://ec.europa.eu/eurostat
Goat Population in Europe	Eurostat	http://ec.europa.eu/eurostat
Cattle population in Europe	Eurostat	http://ec.europa.eu/eurostat
Pig population in Europe	Eurostat	http://ec.europa.eu/eurostat
Livestock population in Czech Republic	Czech Statistical Office	https://vdb.czso.cz/
Livestock population in Denmark	Statbank Denmark	https://www.statbank.dk/
Livestock population in Estonia	Estonian Statistics	http://pub.stat.ee/
Livestock population in Ireland	Central Statistics Office	http://www.cso.ie/
Livestock population in Poland	Statistics Poland	https://bdl.stat.gov.pl/
Livestock population in Slovenia	Statistical Office	http://pxweb.stat.si/
Livestock population in Finland	Statistics Finland	http://statdb.luke.fi/
Livestock population in Sweden	Statistics Sweden	https://www.scb.se/
Livestock population in Switzerland	Federal Statistics Office	https://www.pxweb.bfs.admin.ch/
Livestock population in Norway	Statistisk sentralbyrå	https://www.ssb.no/

ANNEX 3 COMPENSATION SYSTEMS

Compensation systems for livestock killed by large carnivores in different European countries

DOC = Compensation paid for documented losses
CON = Compensation is conditional on effective protection measures
MISS = Only a certain percentage of all claims is inspected so compensation is paid for more than those documented, including many missing animals

Country	System	Evaluation	DOC.	CON.	MISS.
Albania	No compensation system				
Bosnia (Bears, Lynx)	In Federation of Bosnia and Herzegovina: hunting area users, Cantonal Ministry and Federal Ministry.	In Federation of Bosnia and Herzegovina, three-member commission composed of: hunting area users and veterinarian			
	In Republic of Srpska, hunting area users, city administration and Ministry	In Republic of Srpska, three-member commission composed of: hunting area users, city administration and veterinarian	X		
Bosnia (Wolves)	No compensation system				
Bulgaria (Bears, Lynx)	Governmental Insurance Institute				
Bulgaria (Wolves)	No compensation system				
Croatia	Ministry of Environmental Protection and Zoning	Trained and authorized damage inspectors	X	X	
Czech Republic	Paid by the relevant regional authority, Funds from Ministry of Finance	Officer from local authority or local zoologist from Protected landscape area	X		
Denmark	The Danish Agency for the Environment	Trained experts from The Danish Agency for the Nature	X	X	
Estonia	Environmental Board, funds from Estonian Environmental Information Centre	Trained experts from the Environmental Board	X		
Finland	Ministry of agriculture and forestry	Municipality agricultural secretary in cooperation with the person of the	X		

		local game management association			
France	Ministry of Ecological and Solidarity Transition	National Office of Game and Wildlife (ONCFS), National or Landscape Parks for field investigations	X		
Germany	Differences between federal states: Some fincanced by NGOs but in general State money	Trained persons from the rural district or trained volunteers or states hired persons	X	X	
Greece	Hellenic farmer's insurance organization (ELGA)	Veterinarians from ELGA	X		
Hungary	No compensation system				
Italy (Lynx)	Regional level	Forestali Carabinieri, Corpo Forestale Regionale, guardia caccia			
Italy (Bears)	Regional level	Trained local government personel			
Italy (Wolves)	In Piemonte there is an insurance since 2012	Veterinarians from the Sanitary National Service	X	X (only in some regions)	
	In other regions in the Alps, the Regions or the Provinces pay	Personnel of the Provinces or the veterinarians of the ASL			
	If damage in National Parks Regions compensation paid with money from the Ministry of Environment.	Veterinarians or guards of the Parks	X		
Kosovo	The State	Relevant governmental Inspectors			X
Latvia	No compensation system	No compensation system			
Lithuania	Municipalities pay from their environmental funds	Special commission from municipalities	X	X	
Luxembourg	Ministry of the Environment	Ministry of the Environment	X	X	
Macedonia	No compensation system				
Netherlands	Government agency BIJ12-Faunafonds	Government agency BIJ12-Faunafonds	X		
Norway	Environment Office of the County Governor's Administration, funds from Climate and Environment Ministry	Rangers from State Nature Inspectorate inspect carcasses in the field.			X

Poland	Regional Directorate for Environmental Protection & Director of national park (if damage occurs in National Park)	Regional Directorate for Environmental Protection	X	X	
Portugal	National authority for nature conservation	Rangers and technicians from the National authority for nature conservation	X	X	
Romania	Ministry of environment	Environmental agencies, local veterinarian and representative of the local authorities	X	X	
Serbia (Bears)	Ministry of Agriculture, Forestry and Water Management	Veterinary inspectors or hunting management inspectors	X	X	
Serbia (Wolves, Lynx)	No compensation system				
Slovakia	Regional Environment Offices	Nature conservation authority of the district office	X	X	
Slovenia	Ministry of environment and spatial planning	Damage inspectors from Slovenia Forest Service	X	X	
Spain (Bears)	Regional level	Wardens of the autonomous regions	X		
Spain (Wolves)	Castilla y León, North of the river Duero only pays compensations in the Hunting Reserves	Authorized ranger	X		
	Castilla y León, South of the river Duero, all the damages are paid since 31 May 2016	Authorized ranger	X		
	On other regions the farmers must subscribe an insurance (paid by themselves)	Authorized ranger	X		
Sweden	County Administrative Boards, Sami Parliament (for reindeer)	Trained expert from County Administrative Boards	X	X	
Switzerland	Federal Office for the Environment & Canton	Game warden	X		

1. Semi-domestic reindeer in Sweden are compensated based on the presence of large carnivores, rather than on loss.

This study surveys the current status of large carnivores in Europe and assesses their impact on livestock from the available data on compensation payments and from field research. Recommendations on livestock protection measures are provided, as well on the integration of these into locally adapted holistic management systems.

PE 617.498
IP/B/AGRI/IC/2017-123

Print ISBN 978-92-846-3438-5 | doi:10.2861/317882 | QA-01-18-755-EN-C
PDF ISBN 978-92-846-3439-2 | doi:10.2861/37712 | QA-01-18-755-EN-N