

1 **Supplementary material for:**

2 **The challenges and opportunities of coexisting with wild ungulates in the**

3 **human-dominated landscapes of Europe's Anthropocene**

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Data and methodology used to produce the distribution maps

Data collection: There is a huge amount of distribution information scattered across various national and regional sources, as well as in research papers. Even though this was not always clear or possible, we prioritized data defining presence as the permanent species' habitats (i.e. where a species lives and is able to survive and reproduce; Mader, 2004) rather than areas of only sporadic occurrence. We collected and digitalized distribution maps for each European country to produce continent wide distribution maps. Using the distribution maps provided for many countries in Gill 1990 and Apollonio et al 2010 as a foundation (Table 1), we cross-checked and complemented missing data searching for other maps in official documentation, mammal atlases, the scientific literature, citizen science databases and grey literature. Official documentation could include vehicle-ungulates collisions, hunting bag reports as well as government agencies' mapping websites such as <https://lepus.unine.ch/carto> and <http://carmen.carmencarto.fr> for Switzerland and France respectively. When no spatial data was available we referred to textual descriptions about the species' distribution contained in Apollonio, Andersen and Putman (2010). It should be noted that due to poor monitoring efforts for some species in some countries, the time span separating the most recent from the oldest data is up to 39 years! As a result, the quality and accuracy of the data available varies widely between species and countries and it was not always possible to evaluate its accuracy. There is therefore a need to view these products as simply the best available continent-wide maps that were possible to develop with existing information, and a major improvement on existing information which is widely used in large scale analyses (i.e. the IUCN Red List maps www.iucn.org; see Santini et al. 2019 for an example.)

Map production: After extracting the distribution maps taken from diverse sources we used QGIS 3.6.1 Madeira to digitalize the data, turning them into raster layers (step 2, figure 1). We projected the raster layers using a shapefile of Europe as a reference point (created using countries borders available at <https://www.diva-gis.org>). This was done using the "Georeferenced raster" tool with a polynomial 1 transformation type. Because most of the data did not explicitly document the

projection system, by default we assumed it to be ETRS89, the most common projection systems for Europe. We adjusted the number of points necessary to project the raster depending on how well the raster overlaid with the European shapefile (step 3, Figure 1).

Following these first steps we overlaid a pixelated grid with cells of 10km² on each on the raster layers. The cell size was chosen to be consistent with many of the sources, most of which represented presence of a species at a resolution of 10km². The difference in projection system and the digitalization process of the distribution maps rendered a perfect overlay between our pixelated grid and the raster impossible. We considered one of our grid cells as being “presence” if at least 50% of its area overlapped with a presence on the underlying raster. For Austria and in a few other cases the only data available was a regional density map. Even though it overestimates the presence of a given species in a low-density region, we considered a cell as being “presence” if it was located in a region with a non-null density of live animal or harvest, depending of the data available (step 4, figure 1). The pixelated grid with highlighted presence was exported into a shapefile. This process was repeated for each species in each country (step 5, Figure 1). Finally, we merged the species-specific shapefiles to produce the distribution maps for each species.

In three cases we relied on expert knowledge to complete and correct the distribution maps. Norwegian maps for moose, red deer and roe deer in Apollonio et al. 2010 were made from municipality scale hunting bag data. This overestimates their distribution range, especially in the mountainous areas (Erling Solberg, Personal communication). Because these species can be seen sporadically but don’t normally live year-round in mountainous areas we considered a cell absence if more than 50% of its area was above tree line. The moose distribution map was also incomplete in the north of Sweden. We considered a cell as being “presence” if its area contained at least 10% of boreal forests (Following Erling Solberg Personal communication). In a few cases we had to work on data provided by expert assessment which simply indicated that the species was present

“throughout” a given administrative unit. In these cases we recorded all cells within that unit as “presence”.

Although this heterogeneity of data makes the fine-scaled accuracy hard to assess, our focus was on producing a continental wide distribution map that was as good as possible.

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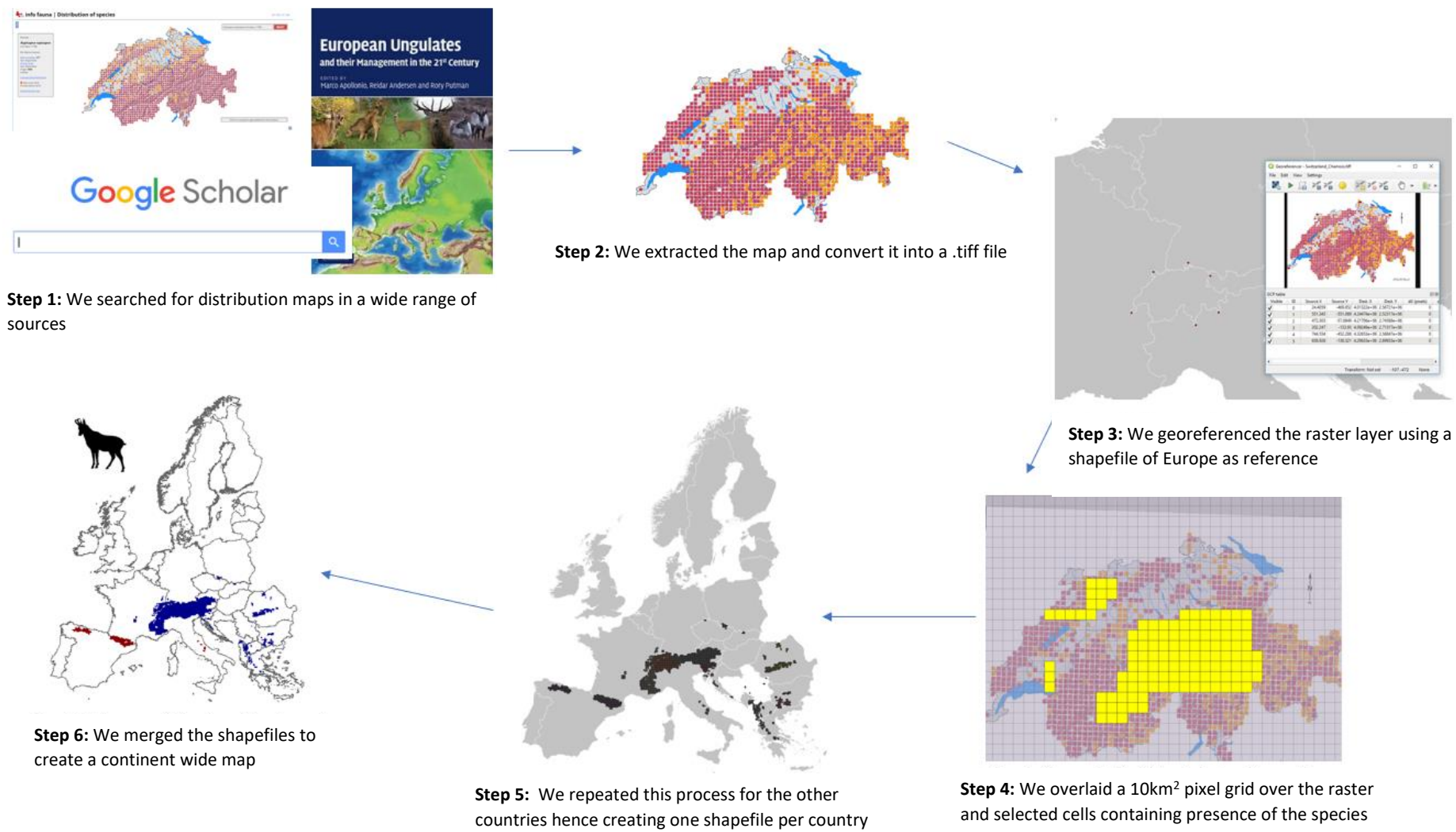
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 320

Countries	Species	Source
Albania	Chamois, red deer, roe deer, wild boar	Trajçe A (Unpublished data)
	Chamois, roe deer	Ivanov et al. (2008)
Austria	Roe deer, red deer, fallow deer, sika deer, mouflon, chamois, alpine ibex, wild boar	Reimoser and Reimoser (2010)
	Roe deer	Duscher et al. (2015)
	Chamois, roe deer, red deer, wild boar	Huber and Bergier (2006)
Belgium	Red deer, roe deer	Caesar and Licoppe (2010)
	Red deer, roe deer, wild boar, fallow deer	Instituut natuur- en bosonderzoek (2018)
	Red deer, roe deer, wild boar, fallow deer, mouflon	Direction générale opérationnelle de l'agriculture, des ressources naturelles et de l'environnement (2018)
Bulgaria	Chamois, red deer, roe deer, wild boar, mouflon	Zlatanova D (Unpublished data)
	Wild boar	Bosch et al. (2014)
	Fallow deer	Chapman and Chapman (1980); Gill (1990)
Croatia	Red deer, roe deer, fallow deer, alpine chamois, mouflon, wild boar	Kusak and Krapinec (2010); Prpić et al (2015); Huber (Personal communication)
	Red deer	Jemeršić et al. (2014)
Czech Republic	Chamois, moose, red deer, roe deer, wild boar, sika, mouflon, white tailed deer, fallow deer	Bartoš et al. (2010), Andera (2019)
	Red deer, moose	Romportl et al. (2017)
	Sika deer	Barancekova et al. (2012)
Denmark	Roe deer, red deer, fallow deer	National center for Environment and Energy (2014)
	Roe deer	Olesen, Asferg and Forchhammer (2010)
	Red deer, sika deer, fallow deer	Asferg, Olesen and Andersen (2001); Andersen and Madsen (2007)
Estonia	Moose, red deer, roe deer, wild boar	Balčiauskas (2009); Estonian Environment Agency (2017); Mannil (Personal communication)
Finland	Moose, white tailed deer, roe deer, fallow deer, forest reindeer	Finnish wildlife agency and Finnish Game and Fisheries Research Institute (2014); Ilpo (Personal communication)
	Moose, roe deer	Ruusila and Kojola (2010); Finnish traffic agency (2014)
	Wild boar, white tailed deer	Kukko and Pusenius (2018)

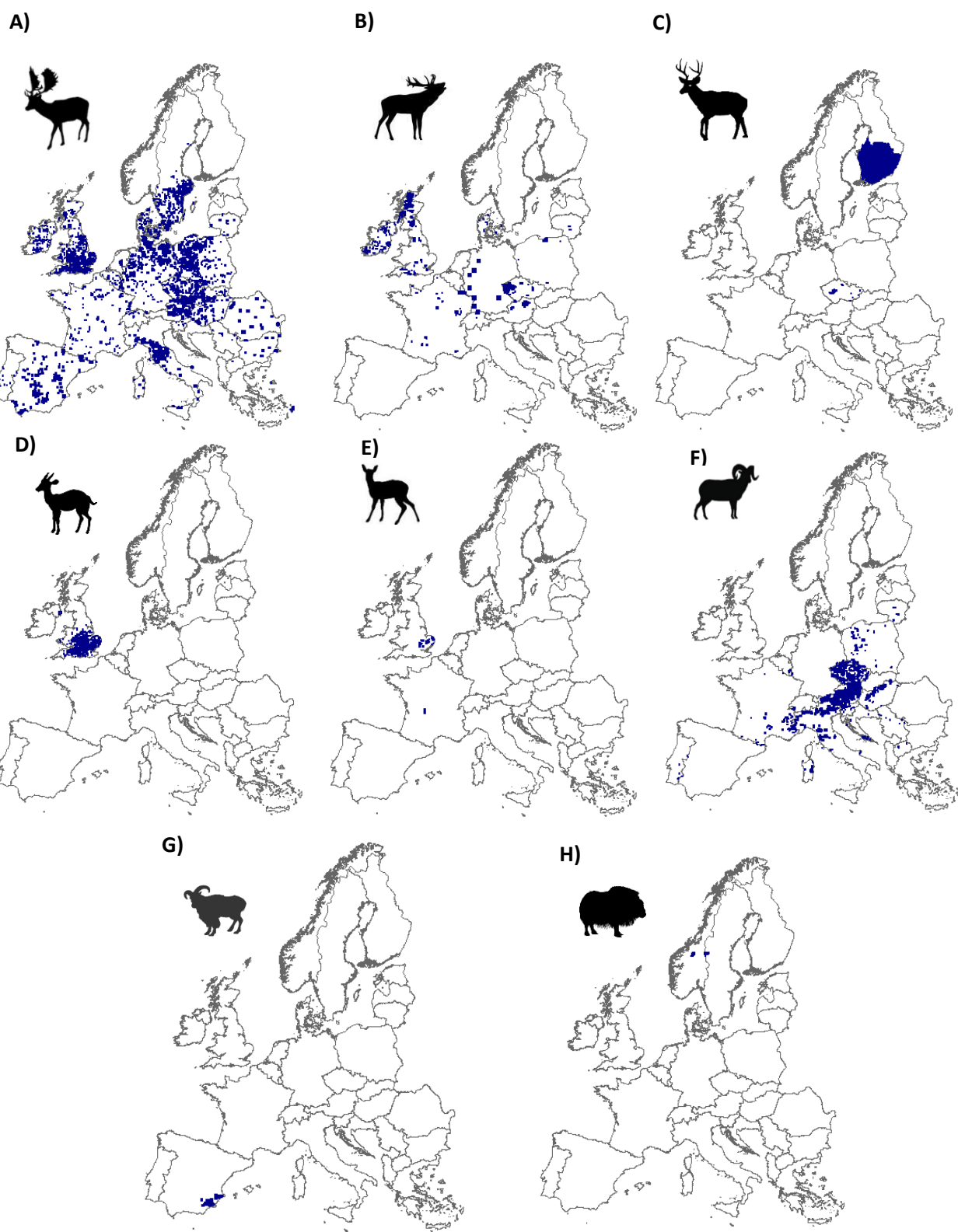
France	Wild reindeer	Natural Resources Institute Finland (2018)
	Roe deer, red deer, chamois, isard, mouflon, wild boar, fallow deer, sika deer, fallow deer	Maillard et al. (2010); ONFCS (2018), Inventaire National du Patrimoine Naturel (2018)
Germany	Chamois, alpine ibex, red deer, roe deer, wild boar	Wotschikowsky (2010)
	Roe deer, red deer, wild boar	Wildtier Kataster (2018)
	Roe deer, red deer, fallow deer	Schettler et al. (2006)
	Roe deer, fallow deer, mouflon	Kauffman et al. (2017)
	Sika deer	Genovesi and Putman (2006)
	Wild boar	Zeit online (2009); Wotschikowsky (Personal communication)
Great Britain	Fallow deer	Petrak (2019); Borkenhagen (1993); Gill (1990)
	Moose	Schönfeld, 2009
	Red deer, roe deer, wild boar, sika deer, chinese water deer, muntjac, fallow deer	Putman (2010)
	Roe deer, red deer, fallow deer, sika deer, muntjac, chinese water deer	Alastair (2005), Walker (2015)
	Wild boar	Aebischer (2011)
Greece	Red deer	Legakis and Maragou (2009)
	Roe deer	Sfougaris and Tsapiris (2009)
	Alpine chamois	Papaioannou and Kati (2007)
	Wild boar	Tsachalidis and Hadjisterkotis (2009)
Hungary	Fallow deer	Papaioannou (2009)
	Red deer, roe deer, fallow deer, mouflon, wild boar	Csányi and Lehocski (2010)
Italy	Red deer, roe deer, wild boar	Bleier et al. (2012)
	Fallow deer, red deer, roe deer	Ács and Hayward (2016)
	Roe deer, red deer, sika deer, fallow deer, mouflon, chamois, isard	Pelliccioni, Riga and Toso (2013); Apollonio et al. (2010)
	Roe deer	Biosa et al. (2015)
Ireland	Wild boar	Apollonio et al. (2010)
	Alpine ibex	De Danieli and Sarasa (2015)
	Red deer, sika deer, fallow deer, muntjac	Carden et al. (2011); Lysaght and Marnell (2016)
Latvia	Moose, red deer, roe deer, wild boar	Latvian state forest service (2019)
Lithuania	Moose, red deer, roe deer, wild boar, fallow deer, mouflon, sika deer	State Scientific Research Institute Nature Research Centre (2015)
Luxembourg	Red deer, roe deer, wild boar, mouflon, fallow deer	Schley et al. (2018); Schley (Personal communication)
Macedonia	Roe deer, wild boar, chamois, red deer, fallow deer, mouflon	Stojanov et al. (2010)
	Chamois, roe deer	Ivanov et al (2008)

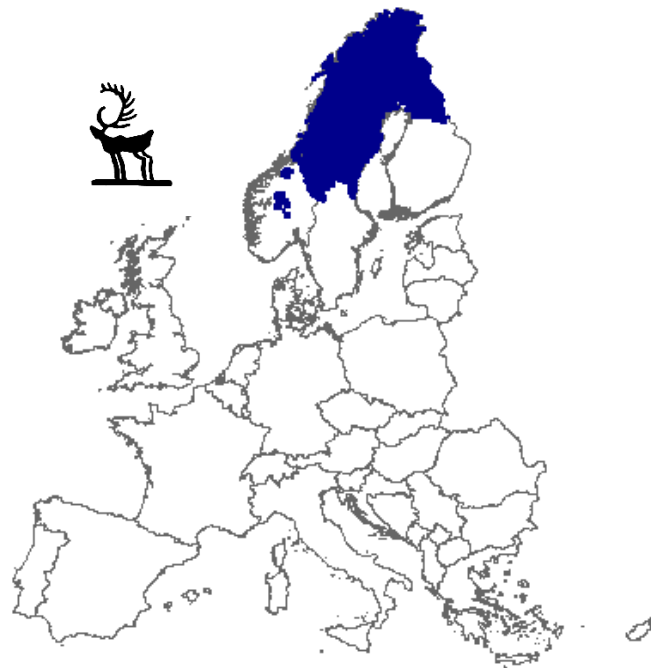
Netherlands	Red deer, wild boar, fallow deer Roe deer	van Wieren and Groot Bruinderink (2010) De Vries (2015); Kenniscentrum Reeën (2003)
Norway	Moose, roe deer, red deer, wild reindeer, muskox	Andersen et al. (2010); Norwegian Biodiversity Information Center (2018); Solberg, pers comm.; Statistics Norway (2018)
	Wild boar	Rosvold and Andersen (2008)
Poland	Chamois, moose, red deer, roe deer, wild boar	Wawrzyniak et al. (2010); Instytut Ochrony Przyrody (2018)
	Fallow deer, mouflon	Instytut Ochrony Przyrody (2018)
Portugal	Roe deer, red deer, wild boar, mouflon, fallow deer	Vingada et al. (2010)
	Roe deer	Torres et al. (2015)
	Wild boar	Santos et al. (2006)
Romania	Chamois, red deer, roe deer, wild boar	Ovidiu (Unpublished data)
	Fallow deer	Chapman and Chapman (1980); Gill (1990)
	Wild boar	Cadar et al. (2011)
		Ćirović (Unpublished data)
Serbia	Chamois, alpine ibex, red deer, roe deer, wild boar, mouflon, fallow deer	
	Fallow deer	Chapman and Chapman (1980)
Slovakia	Chamois, red deer, roe deer, wild boar, mouflon, fallow deer	Findo and Skuban (2010), National Forestry Center (2016)
Slovenia	Chamois, alpine ibex, red deer, roe deer, wild boar, mouflon, fallow deer	Adamic and Jerina (2010); Krofel (Personal communication)
	Roe deer	Konjevic et al. (2011); Pokorny (2006)
	Wild boar	Štukelj et al. (2014)
	Chamois	Buzan et al. (2013)
Spain	Red deer, roe deer, wild boar, barbary sheep, mouflon, fallow deer	Carranza (2010)
	Wild boar, red deer, Iberian ibex, roe deer	Acevedo (2011)
	Wild boar	Bosch et al. (2012)
Sweden	Red deer, roe deer, wild boar, fallow deer, moose	Swedish Hunting Associations (2018)
	Red deer, roe deer, wild boar, fallow deer	Liberg et al. (2010); Solberg (Personal communication)
	Moose, muskox	Swedish Species Information Centre (2018)
	Moose	Wennerström et al. (2015); Solberg (Personal communication)

Switzerland	Chamois, alpine ibex, red deer, roe deer, wild boar, sika deer, fallow deer	Centre Suisse de Cartographie de la Faune (2018) ; von Arx (Personal communication)
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Map 1: Introduced ungulates distribution in Europe. A) Fallow deer, B) sika deer, C) white tailed deer, D) Reeves's muntjac, E) Chinese water deer, F) mouflon, G) barbary sheep, H) muskox





358 **Table 2:** detailed number of large ungulates harvested in Europe for the most recent year available

Countries	Years	Total shot per year	Wild Boar	Roe Deer	Red deer	Moose	Fallow deer	Sika deer	Wild reindeer	White-tailed deer	Other deer	Chamois	Mouflon	Iberian Ibex	Barbary sheep	Alpine Ibex	Source
Germany	2017	2,111,695	836,865	1,190,724	76,794			2,429				4,883					https://www.jagdverband.de/
France	2017	1,421,958	756,149	585,925	62,418		1,455	61				12,699	3,251				http://www.oncfs.gouv.fr/
Poland	2017	660,100	341,400	214,800	94,400		9,500										Statistical book of forestry 2018 / 2019
Austria	2017	413,355	40,297	285,718	61,545		870	879				21,048	2,379			619	http://statcube.at/
Czech Republic	2017	383,584	229,182	103,455	27,878		23,069						9 400				https://www.czso.cz/
Spain	2010	371,377	207,159	29,935	112,252		10,846						7,325	3,219	641		http://www.fecaza.com/
Sweden	2017	354,305	114,831	103,396	10,494	84,754	40,830										https://rapport.viltdata.se/
Hungary	2017	249,608	102,600		101,464		34,725						10,819				http://www.vvt.gau.hu/
Slovakia	2016	132,106	53,788	25,627			10,593				35,268	1,446	5,384				http://datacube.statistics.sk/
Bulgaria	2013	123,654	49,513	64,889	6,295		2,205					470	282				http://www.slr.org/
Denmark	2017	116,086	190	96,193	9,927		9,199	504					73				http://fauna.au.dk/
Scotland	2017	115,037		42,543	61,640		3,093	7,761									https://www.nature.scot/
Norway	2017	111,816	226	33,280	42,541	31,613			4,156								https://www.ssb.no/
Finland	2017	107,849	571	9,392		56,581	101		22	41,162			20				http://statdb.luke.fi/
Switzerland	2017	83,200	11,346	44,394	14,611							11,655				1,194	https://www.bfs.admin.ch/
Italy	2005	187,059	114,831	46,507	7,978		4,424					12,373	871			75	ISPRA, 2009
Latvia	2017	70,066	25,549	22,135	15,330	7,052											https://data1.csb.gov.lv/
Lithuania	2016	63,792	32,624	23,828	5,266	1,796	278										https://osp.stat.gov.lt/
Slovenia	2017	56,150	12,238	34,156	7,425							2,331					https://pxweb.stat.si/
Croatia	2017	49,645	30,000	15,400							4,245						https://www.dzs.hr/
Estonia	2015	46,969	32,580	6,264	1,252	6,873											https://www.stat.ee/
Belgium (Wallonie)	2016	45,930	21,721	19,272	4,635		139						163				http://biodiversite.wallonie.be/

Romania	2012	29,496	19,965	7,457	1,617		457										http://www.mmediu.ro/
Luxembourg	2017	14,052	6,520	6,868	468		144						52				https://environnement.public.lu/
Belgium (Flanders)	2017	7,379	1,550	5,762	5		62										https://pureportal.inbo.be/
TOTAL		7,326,268	2,204,830	1,827,196	649,441	188,669	151,990	9,205	4,178	41,162	39,513	62,022	30,619	3,219	641	1,888	

