Chapter 9
Alien Mammals of Europe

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9.1 Introduction

Mammals are large, charismatic animals that have a mineralised skeleton that may form long lasting fossils. For these reasons, the level of knowledge on this class, together with other vertebrates, is much higher than for any other animal group. Therefore, the available information on introduction patterns, trends of invasions, and detrimental impacts caused to the environment and to human well-being are more detailed than for other groups covered in the DAISIE project.

History of mammal invasions is very long, as anthropogenic introductions of mammals started at least since the beginning of the Neolithic period. Ancient introductions involved wild species commensal of humans (i.e., black rat *Rattus rattus* and house mouse *Mus musculus*), anthropophilous (i.e., lesser white-toothed shrew *Crocidura suaveolens* and wood mouse *Apodemus sylvaticus*) and domestic species (i.e. species domesticated in the Middle East and gone feral, like the Corsican mouflon *Ovis aries*). Data on alien mammals have been collected from available global reviews (Long 2003; Mitchell-Jones et al. 1999; Lever 1985), national inventories (Austria: Englisch 2002; Denmark: Baagøe and Jensen 2007; France: Pascal et al. 2006; Germany: Geiter et al. 2002; Ireland: Stokes et al. 2006; Italy: Andreotti et al. 2001; Scalera 2001; Liechtenstein: Broggi 2006; Scandinavian countries: Weidema 2000; Spain: Nogales et al. 2006; Palomo and Gisbert 2002; Switzerland: Wittenberg 2006; the UK: Battersby and Tracking Mammals Partnership 2005; Weijden et al. 2005). Databases available on the internet were also used as a source of information (i.e. for Belgium, the Nordic countries, etc.). Other data have been collected through inputs of the experts of the DAISIE consortium, but also with the valuable support of many experts of the IUCN Invasive Species Specialist Group and of the Group of Experts on Invasive Alien Species of the Council of Europe. Independent experts have verified each record, which included information on taxonomy, native range, vector and pathway of introduction, date of introduction, status of the species, basic information on population size, distribution and impacts.

Based on the DAISIE database, in the present chapter we present an overview of the main patterns of mammal invasions in Europe, and analyse the main environmental, social and economic correlates to the arrival and successful establishment.

DAISIE, *Handbook of Alien Species in Europe,*

9.2 Description of the Mammal Inventory

For the DAISIE mammal inventory we only took into consideration invasions that occurred since 1500. The DAISIE dataset includes records of 88 mammal species introduced since 1500 in one or several of the 52 European geographic entities considered for the data collection (43 countries, including Russia, and nine islands or island systems, hereafter called regions, i.e. south Aegean islands).

Of the 88 species listed in the database four have an uncertain status, like the European mink *Mustela lutreola*, considered of uncertain origin in France by Pascal and co-authors (2006), or the Russian desman *Desmana moschata* in Moldova and Lithuania, where it is not known if the species was introduced or arrived naturally. Of the remaining 84 species, 64 (75%) are alien to the European continent, while 20 (25%) are native to at least one European region, but introduced in other country or island of the region, outside their native European range. Of the 20 species native to some countries of Europe, 14 (70%) have established self-sustaining populations in the areas of introduction, while four have become extinct. Moreover, the hamster *Cricetus cricetus* in Denmark has an "unknown" status (NOBANIS 2007), and the beluga *Delphinapterus leucas*, the only known case of an alien cetacean introduced into Europe, is considered "not established" (Reeves and Notarbartolo di Sciara 2006).

Of the 64 non-European aliens, 33 (52%) are considered established, that is, they form self-sustaining populations, in one or more regions, and 20 (31%) are reported as extinct. Among the extinct species, the case of the Himalayan porcupine *Hystrix indica*, escaped from a zoological garden and established in the wild in Devon in the late 1970s, is particularly interesting, because this is the only species which has been intentionally eradicated (Genovesi 2005) and as a result it is now no longer present anywhere in Europe. Seven out of these 64 species are listed as present but not established. However it should be noted that some species quoted as extinct according to the DAISIE database (porcupine *Hystrix cristata*, barbary macaque *Macaca sylvanus*, house mouse and black rat) are actually established if we also consider populations introduced before 1500. In conclusion, we consider that the number of extant alien mammals species in Europe is 44, while additional 15 species have been intentionally or accidentally moved from one European country/region to another.

To estimate the proportion of alien species in the European mammal fauna, we integrated and compared the DAISIE dataset on alien mammals introduced after the year 1500, with the results of the European Mammal Assessment (Temple and Terry 2007), that has the same geographic coverage as the DAISIE project. The European Mammal Assessment comprises 312 species, but excluding introduced species, extinct and domestic forms, the number of native mammal species in Europe drops to 245 including the above mentioned species with uncertain origin. We did not exclude species classified as having marginal occurrence by the European Mammal Assessment, because the DAISIE dataset also includes alien species which have a very limited range in Europe (e.g., Pallas squirrel *Callosciurus erythraeus* in Antibes, France). Alien species account for 15% of species present in

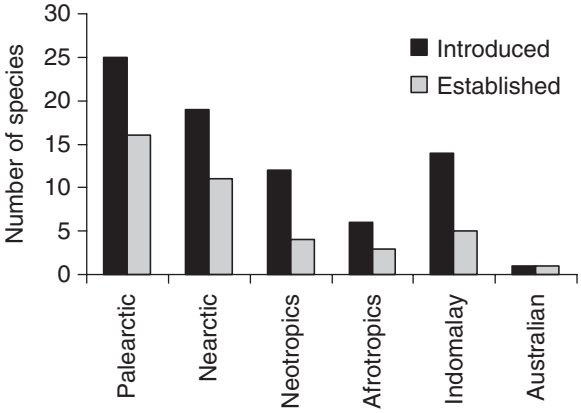

Fig. 9.1 Origin of introduced mammals in Europe

Europe. However, if we consider only terrestrial mammals, the percentage of alien vs. native species raises to 21%.

Of the 64 (75%) non-European aliens, the most frequent area of origin is the non-European Palearctic (29%), followed by Nearctic (22%), Indomalay (16%), Neotropics (14%), Afrotropics (7%), and Australian (1%) (Fig. 9.1). (Several species occur in more than one biome.) With regard to taxonomy, of the 84 species introduced into Europe, 30 belong to the order Rodentia, 24 are Artiodactyla, 12 Carnivora, six Lagomorpha, and two Erinaceomorpha. As previously mentioned, we also recorded the introduction of a cetacean, the beluga *Delphinapterus leucas* escaped from captivity in the Caspian sea, but there are also cases of introductions of two bat species, one of which succeeded, the large Egyptian rousette *Rousettus aegyptiacus* in the Canary islands (Nogales et al. 2006) and one marsupial, the red-necked wallaby *Macropus rufogriseus*, currently established in France and the UK (Long 2003; Pascal et al. 2006) (Fig. 9.2).

9.3 Temporal Trends of Invasion

Considering all introductions reported at the national level for which a date of introduction is known (n = 386 introduction events recorded in Europe), there is an evident exponential increase in the number of introductions since the end of the 19th century (Fig. 9.3). Moreover, considering only the 64 species that are not native of Europe, the number of alien species that has been introduced in this continent has constantly grown in the last centuries (Fig. 9.3).

The rapid rate of invasion is particularly evident if we consider the introductions of non-European aliens after 1850, where there is a clear linear correlation (1850–2000: $y = 0.3807x - 706.36$, $R^2 = 0.99$). Moreover, it should be noted that the trend

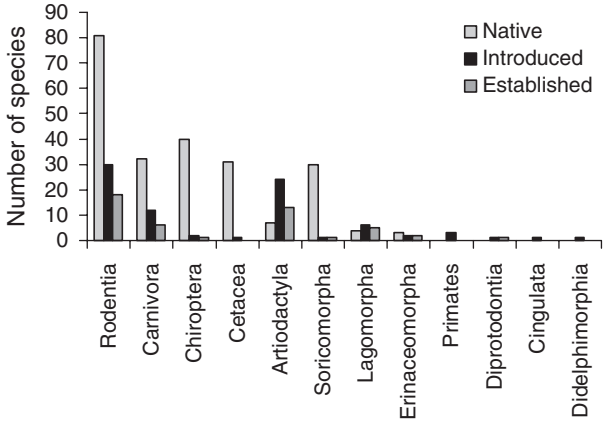

Fig. 9.2 Taxonomy of native, introduced and established mammals in Europe. Number of native species excerpted from the European Mammal Assessment carried on by the IUCN (Temple and Terry 2007). Species introduced before 1500 and domesticated species are not considered

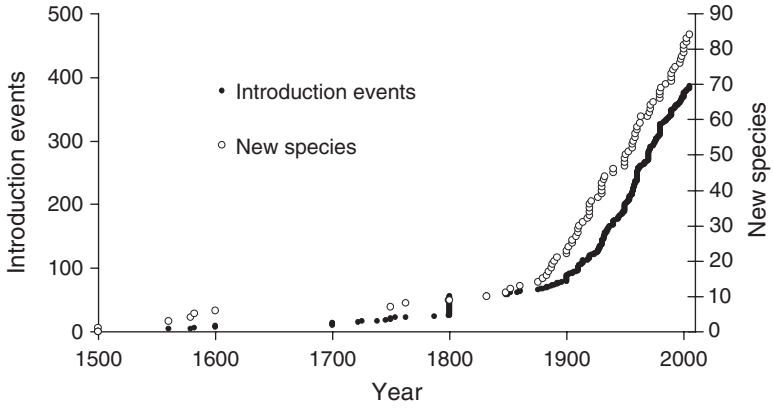

Fig. 9.3 Trends of mammal invasions in Europe: number of introduction events occurred since 1500 (n = 386 with exponential growth y = 1E-07e0.011x) and cumulative number of alien species invading Europe (66 non native alien species established in Europe ($y = 4E\text{-}0.6e^{0.0081}x$, $R^2 = 0.889$)

is constant and does not show any saturation effect and is similar to that found for example in France by Pascal et al. (2006). This pattern appears to confirm that ecological systems rarely show evidence of being saturated with species (Sax et al. 2007). Similarly, the number of alien mammal species successfully established per year confirms the rapid increase of biological invasions in Europe. In fact, this rate has grown from 0.03 species successfully introduced per year before 1800, to one species per year recorded in the last 5 years (Fig. 9.4).

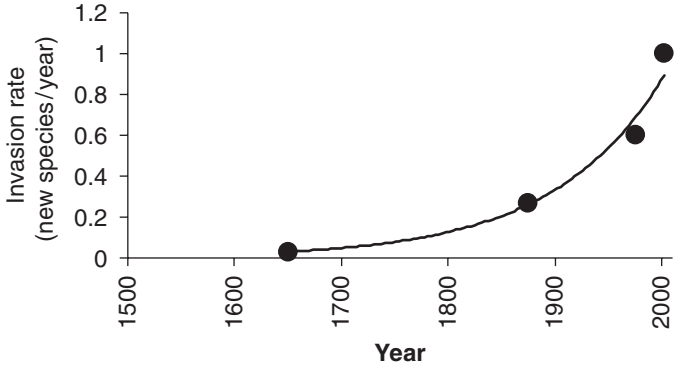

Fig. 9.4 Rate of arrival of new species in Europe (four periods: 1500–1800, 1800–1950, 1950–2000, 2000–2005. Exponential growth: y = 4E-09e0.0096, $R^2 = 0.99$)

9.4 Main Pathways to Europe

The most frequent pathway of alien mammals introduction in Europe is intentional release from captivity, which accounts for 35% of all known cases of introduction (n = 411 cases at the national level, 321 with known vector, 90 unknown). If we consider the activities related to invasions by alien species, fur farming has been at the origin of 15% of all recorded cases, hunting 21%, release or escape of pets 10%, and escapes from zoos 6% (n = 266). The so called "fauna improvement" is the wrong concept of "improving" the number of species in an area by intentionally releasing other species. Also "mistaken" reintroduction programmes carried on with species similar to the native ones (i.e., introduction of the Canadian beaver *Castor canadensis* in Finland, due to a confusion between this species and the native European beaver *Castor fiber*) were performed. Both account for 7% of the known introductions. In total 31% of introductions occurred unintentionally, through the inadvertent movement of species due to global trade.

The pathways of introduction have changed very much in the last centuries, showing a decrease in the role of unintentional transport, and an increase of the escapes and of the spread of established populations (Fig. 9.5). The number of intentional introductions is decreasing, probably due to an increasing awareness on the problems related to biological invasions. It is interesting to note that, considering only those introduction events that occurred since 1960 (n = 100), a large proportion of introductions were from fur farms (23%), hunting (17%) and pet trade (15%). Moreover, if we only consider the last 10 years (1997–2007), eight intentional and 11 unintentional introductions have occurred. Cases of intentional introductions include the release of captive animals for ornamental purposes, for "fauna improvement", or for hunting (i.e. aoudad *Ammotragus lervia* and eastern cottontail *Sylvilagus floridanus*).

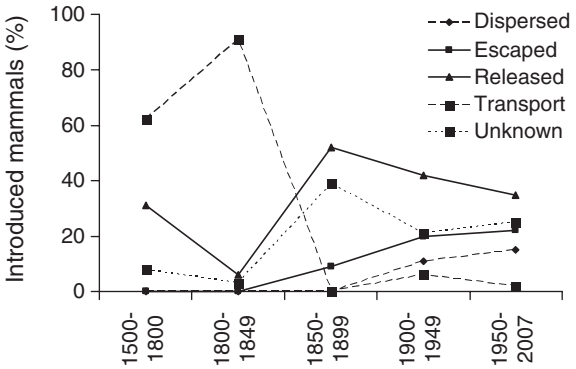

Fig. 9.5 Changes over time of the role of major vectors responsible of the introduction of mammals in Europe

9.5 Biogeographic Patterns

The number of introduced species per country (excluding those of uncertain origin) varies from 1 to 31 (average 7.9), while the number of established species per country ranges from 1 to 12 (average 4.9). Both numbers of introduced and established mammal species per country correlate to country area (R^2 = 0.33 and R^2 = 0.5 respectively).

The average success rate (calculated as the ratio between number of established and introduced species per country) is 0.72 (±0.22), much higher than what would be expected following the Ten's rule (Williamson 1996). This high invasion success rate can be explained partly with a possible bias in the database (successful introductions are more likely to be reported than unsuccessful ones), but it is also likely due to a high success rate of mammals invasions in suitable environments, confirming the conclusions of previous studies (e.g., Jeschke and Strayer 2005). The most widespread species (established in over 10 European countries) are brown rat ***Rattus norvegicus***, muskrat ***Ondatra zibethicus***, American mink ***Mustela vison***, raccoon dog ***Nyctereutes procyonoides***, coypu ***Myocastor coypus***, fallow deer *Dama dama*, sika deer ***Cervus nippon*** and raccoon ***Procyon lotor***. Interestingly, all these widespread species are not native to Europe, and all cause rather significant impacts in the invaded areas.

The most invaded countries (Fig. 9.6) are Germany, with 31 species, and the UK with 30, followed by Denmark (18), mainland France (16), the Czech Republic (16), Russia (15) and Italy (14). However the order changes when considering established species only: in this case Russia with 12 species is the most invaded country, followed by mainland France with 10 species, Germany and the UK (9 each), and the Czech Republic, Ukraine, Sweden, Austria and Belgium (8 each). The difference is due to the high number of extinct species recorded in countries like the UK and Germany where 18 and 15 species disappeared after introduction, respectively. It should be noted that the information stored in the DAISIE database

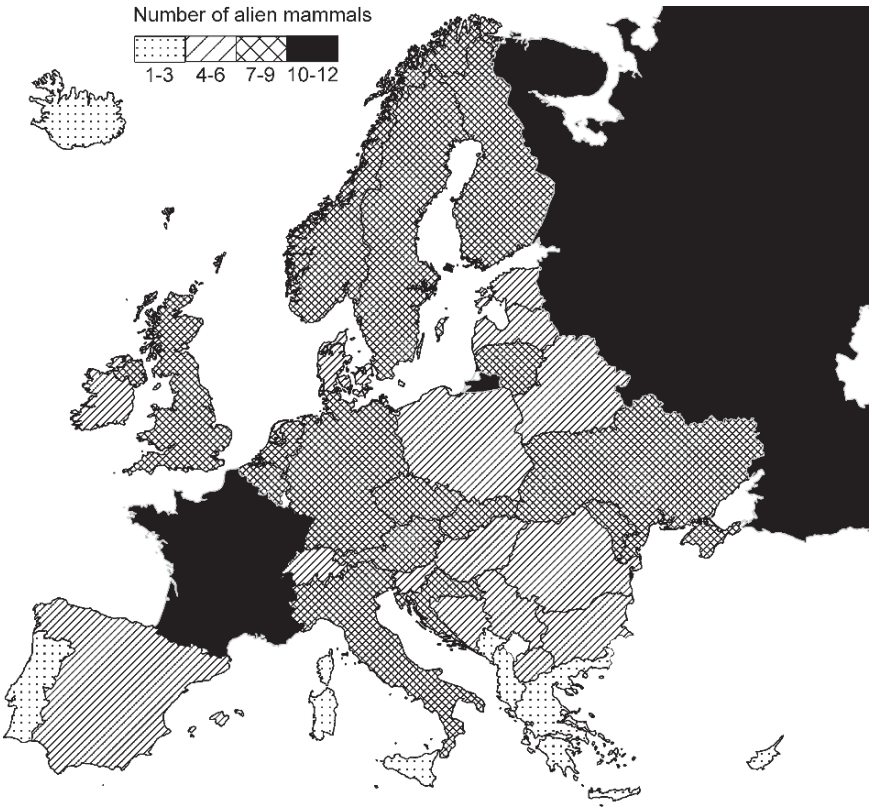

Fig. 9.6 Number of established alien species per country

may be geographically biased, with cases of undetected or unreported invasions in areas with less monitoring activities, for example in some eastern European countries.

If we analyse the number of established alien mammals in European countries in respect to the geographic location of the country, there is a hump-shaped latitudinal pattern, with an increase in the number of species from subtropic to central Europe, and a subsequent decrease in the extreme northern areas (Fig. 9.7); while it does not seem to be any significant relationship with longitude ($R^2 = 0.047$).

9.6 Impacts on Ecology, Ecosystems and Economy

If we consider the whole set of species in the databases, which includes also those not established or with unknown status (some of which could get established in the future), and excluding species extinct in all countries (24 species), the number of

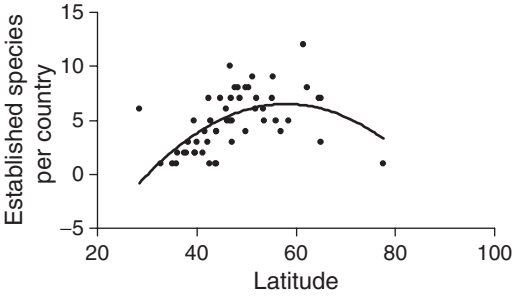

Fig. 9.7 Quadratic correlation between number of established species and latitude (n = 52 regions, $R^2 = 0.33$)

alien mammals causing known ecological impact (in the countries where they have been introduced or elsewhere) is 37 (58%). The number of those with a known impact on human activities (e.g., causing damage to crops, riverbanks, livestock, etc.) or health is 40 species (63%). However, the percentages increase sharply if we limit our analysis to the subset of the 50 established species. In this case at least 34 species (68%) have a known ecological impact. The number of species with a known impact on uses/resources is even higher: 36 (72%). The impact of the remaining species is unknown meaning that it has not been evaluated.

Also in this case the available data on alien mammals in Europe seem to contradict Williamson's Tens rule, confirming the much higher impact caused by this group compared to others. The mechanisms of the impacts caused by alien mammals to European biodiversity are very variable, from direct predation (the American mink threatening native water vole *Arvicola terrestris* in the UK), to competition (American grey squirrel ***Sciurus carolinensis*** outcompeting the native red squirrel *S. vulgaris*, causing its extinction in all areas of overlap), to hybridisation (sika deer threatening the genetic integrity of red deer in Scotland through interbreeding). Alien mammals also cause huge impacts to European economy and well-being, like coypu damaging crops and weakening the stability of river banks through digging, causing in Italy alone losses over 4 million Euros/year (Panzacchi et al. 2007), not to mention the epidemiological role played by several rodent species, including rats and the Siberian chipmunk ***Tamias sibiricus*** (Vourc'h et al. 2007).

9.7 Management Options and Their Feasibility

Matching the particularly severe impacts that alien mammals cause, many species are subject to some kind of control management in Europe. In particular, all the most widespread species (coypu, muskrat, rats, American grey squirrel, raccoon, raccoon dog, sika deer, American mink, fallow deer) are controlled in several coun-

tries and some have also been subject to eradication programs. Moreover, removal methods by trapping, shooting, etc. are more developed for mammals than for any other vertebrate, and in fact most eradications carried out in Europe have targeted mammal species, such as rats, American minks, coypu, Canadian beaver or Himalayan porcupine (see Genovesi 2005 for a review).

On the basis of the DAISIE dataset, it is evident that there are several species of mammals posing severe threats to regional biodiversity with still very local distribution, making these species very good candidates for eradication programs. Seventeen alien mammals are established in one country only; this is the case of the Pallas squirrel which is only present in Antibes (France); Finlayson's squirrel *Callosciurus fynlaisonii*, only present in Italy with two distinct populations; eastern cottontail, established in Italy; the coati *Nasua nasua* only present in Majorca (Balearic islands, Spain) or three species (Egyptian rousette *Rousettus aegyptiacus*, Algerian hedgehog *Atelerix algirus* and Barbary ground squirrel *Atlantoxerus getulus*) only recorded in the Canary islands (Spain). But the feasibility of an eradication programme should also be considered for several species recorded in more than one country, although still very localised in all or some of the countries; this is the case of the aoudad in Croatia (only present on the Mosor mountain in Dalmatia) and Italy (small population close to Varese), as well as the coypu in northern Spain (present with two very local populations).

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