Chapter 9
Invasive European Wild Rabbits (*Oryctolagus cuniculus*) in Argentina: State of the Art and Prospects for Research

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9.1 The Paradoxical European Wild Rabbit

The European wild rabbit, *Oryctolagus cuniculus*, is simultaneously a threatened species within its native range and yet, a successful colonizer worldwide (Lees and Bell 2008). The European rabbit is native to the Iberian Peninsula, south of France and north of Africa. In the Iberian Peninsula, its populations have undergone a massive decline during the twentieth century as a result of introduced pathogens (including myxoma virus and rabbit calicivirus), overhunting, habitat loss, and changes in land use (Lees and Bell 2008). The rabbit is a keystone species in the Mediterranean ecosystem of the Iberian Peninsula. For example, it is a key food source for more than 30 carnivorous species and a primary prey item for many of them, including critically endangered species such as the Iberian lynx (*Lynx pardinus*) and the Spanish imperial eagle (*Aquila adalberti*) (Delibes-Mateos et al. 2008). It also is an important ecosystem engineer for having the potential to modulate availability of resources for themselves and other organisms by building extensive open burrow systems (Gálvez-Bravo et al. 2008).

Paradoxically, the European rabbit is considered one among the 100 most harmful invasive alien species in the world due to its high plasticity and its impact on biological diversity and human activities (Lowe et al. 2000). The European rabbit is a unique case at global level, because no other invasive species is categorized as endangered in the Iberian Peninsula and, at the same time, viewed as an exotic and destructive threat to be eradicated in other places. The apparent contradiction that the European rabbit presents makes it an excellent model to study basic processes in

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population biology (i.e., life history, demographic models, and so on), evolution (e.g., rapid adaptive evolution), and ecology between its native and invasive ranges.

9.2 The European Wild Rabbit as an Invasive Species

Current generalizations about successful invaders are based on ecological traits of species and characteristics of vulnerability of invaded communities (Mack et al. 2000). Most successful invasive mammals exhibit some of these intrinsic and extrinsic attributes (Novillo and Ojeda 2008). The European rabbit shows remarkable ecological adaptability which is based on its broad diet, environmental tolerance, rapid dispersal, and high reproductive rate (Thompson and King 1994). Other hypotheses proposed about invasion success include predator and competitive release, a similar climate in native and invaded ranges (climate matching), and/or environmental disturbances in invaded habitats (e.g., an increase in annuals and decrease in perennials which typically follows extensive anthropogenic disturbance) (Lees and Bell 2008) (Table 9.1).

Table 9.1 Intrinsic, extrinsic, and human-related factors of the European rabbit, examples and explanations

Factors	Examples	Explanation
Intrinsic		
	Broad diet	Able to feed on different items
	Environmental tolerance	Type of habitat is not a limiting factor
	High dispersal capacity	Advantage to colonize new environments
	High reproductive capacity	Advantage to fast population increase and colonization
Extrinsic		
	Enemy release	Invader lacks its natural enemies (predators, pathogens) in the new habitat
	Climatic matching	Sets of species seem to be limited by climate
	Disturbed environments	Any relatively discrete event in time that increase resource availability and changes in habitats (e.g., herbivory, land-use change)
Associated to human		
	High propagule pressure	Many introduction events (frequency) and/or many individuals per introduction (supply)
	Old date introductions	More time for acclimatization
	Pathway of introduction	Food-valued organism

Furthermore, there are human-related factors that provide important insight into the understanding of successful colonization, such as the historical relationship between human activities and the structure and function of contemporary ecosystems and landscapes (i.e., historical ecology of the invasion) (Delibes and Delibes-Mateos 2015). European rabbits are edible animals that were semi-domesticated some thousands of years ago and have been transported to many places for human use; however, they only persisted in a few localized areas. Thereby, rabbits have been liberated on more than 800 different islands worldwide where this species has consolidated its global distribution (Flux and Fullagar 1992). Delibes and Delibes-Mateos (2015) argue that a high propagule pressure might have been necessary for successful colonization of European rabbit in several continental parts of the world (Table 9.1).

At a global scale, the economic impact of the European rabbit is associated with the high costs involved in its control, the cost of production loss due to vegetation degradation from the high grazing pressure it applies, reduced crop yields, and reduced domestic stock production (Williams et al. 1995). Besides, being a serious vertebrate pest for agricultural production, the European rabbit affects habitat structure, species composition, and ecosystem processes (Vázquez 2002). Particularly, rabbits change the structure of plant communities through herbivory and the structure of vertebrate communities through competition or via their role as a prey species (Courchamp et al. 2003; Davey et al. 2006). For example, in Chile the European rabbit along with cattle have altered the structure and functioning of the sclerophyllous scrub, generating a replacement of this ecosystem by savannas dominated by the native *Acacia caven* shrub (Holmgren 2002). Also, its warren-building behavior increases soil erosion and changes in soil biogeochemical properties (Eldridge and Koen 2008; Eldridge and Myers 2001, Crooks 2002). Rabbits directly compete for food with native herbivorous mammals (Jaksic 1998), birds (Courchamp et al. 2003), and livestock (Jaksic et al. 2002). European rabbits could also indirectly affect native fauna by facilitating mesopredator release and hyperpredation (Courchamp et al. 2000; Lees and Bell 2008).

9.3 History of European Rabbit Invasion and Expansion in Argentina

The history of introductions of the European rabbit in Argentina has been documented by several authors. Delibes and Delibes-Mateos (2015) documented from a sailor's diary that in 1765 a ship named Purísima Concepción shipwrecked near the coast of Tierra del Fuego and the crew introduced rabbits in the island with the intention of being supplied with food. However, nothing is known about the success of this early introduction. In 1880, Thomas Bridges and his sons introduced rabbits in several islands in the Beagle Channel (Bridges 1949, in Jaksic and Yáñez 1983) in order to provide food to castaways and yaganes (natives to the island) (Navas

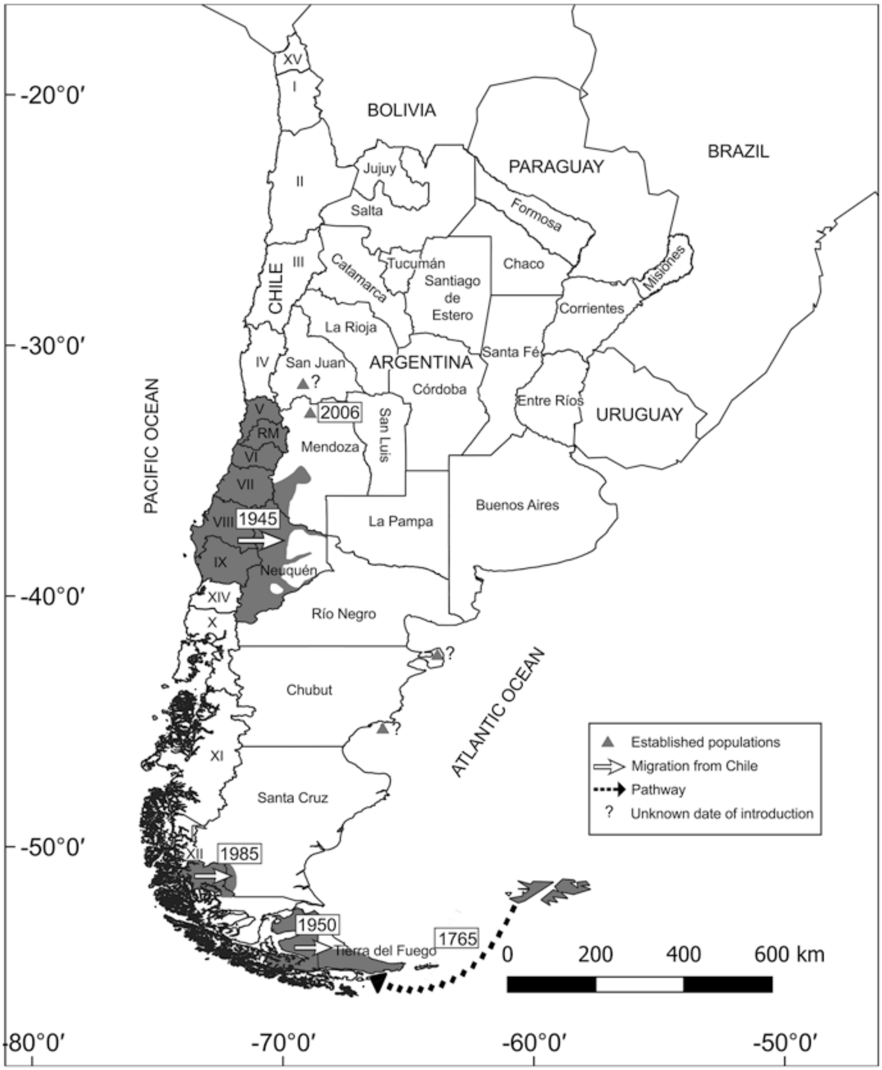

Fig. 9.1 Potential distribution of European rabbit in Argentina

1987). These individuals came from the Malvinas (or Falkland) islands, where they were introduced by French colonists around 1765 (Fig. 9.1). In addition, rabbits were introduced in Observatorio Island, near Ushuaia, in 1902 (Jaksic et al. 2002). A fourth introduction event was detailed by Amaya and Bonino (1981), Jaksic and Yáñez (1983), and Jaksic et al. (2002). In 1936, two pairs of rabbits were released near Porvenir city in Chile. They rapidly spread all over the northern part of Tierra del Fuego Island, arriving in Argentina's mainland and expanding east as far as San Sebastián Bay and beyond Río Grande city to the south (Fig. 9.1). In 1950, Argentinian navy and private farmers released rabbits near Ushuaia city. Between 1950 and 1953, rabbit populations reached an abundance of 30 million individuals (30 individuals/ha). This was considered the worst invasion. Sheep were negatively affected by the impact of rabbits due to their building of burrows and to their grazing habits that leave the ground bare of grass. Therefore, sheep ranchers attempted to control these populations and started hunting and trapping them. Then, they used cyanide gas (that did not work). Later, in 1951, they introduced the gray fox (*Lycalopex griseus*) from the neighboring continental area, and finally, in 1954, they introduced myxoma virus from Brazil. All these actions reduced rabbit populations to a very low level. Another introduction event occurred in Tova and Tovita islands, Chubut province (Udrizar-Sauthier et al. 2017). However, the date of introduction, number of individuals, or status of populations is unknown (Fig. 9.1).

Populations of European rabbits established in five regions of continental Argentina: (1) south of San Juan, (2) north of Mendoza, (3) south of Mendoza and north of Neuquén, (4) east of Chubut, and (5) southwest of Santa Cruz province (Fig. 9.1).

(1) In the south of San Juan province, rabbits were detected in 2005 in El Leoncito National Park (Andino et al. 2008, in Laspina et al. 2013), but there is no information about the status of this species in the area.
(2) In 2006, the staff in the Villavicencio Nature Reserve intentionally released four rabbit couples which belonged to a breeding facility in the same Reserve (Cuevas et al. 2011). Rabbits spread along three corridors: Hornillos Ravine (northwest direction) which extends for 6 km, Darwin Ravine (west direction) which is 3.5 km long, and the third path towards Monte desert foothills (southeast direction) which stretches for 4 km. But after 4 years, rabbits were present only in the first two corridors. In this area, spread of rabbits would be related to movement along riverbed transects and across valleys, probably due to the influence of factors such as vegetation, soil, and moist places (Cuevas et al. 2011).
(3) Within the general area where the provincial borders of Neuquén and Mendoza meet, the first established rabbit population was seen between 1945 and 1950 in the headwaters of the Neuquén River, near Andacollo locality in Neuquén province (36° 80′ W) (Howard and Amaya 1975). These authors suggest that there is circumstantial evidence that rabbit populations in central Chile (brought from Spain) spread to Argentina crossing the Andes Cordillera through passes lower than 1800 m elevation. This dispersal probably occurred during summer, when environmental and habitat conditions are more suitable due to the presence of grass for food and shrubs for shelter (Jaksic et al. 2002). In 1969, Howard and Amaya (1975) recorded that rabbits crossed the Colorado River to the north (arriving in Mendoza province) and the Neuquén and Agrio rivers to the south. Thus, rabbits occupied 31,000 km^2 (with a dispersal rate of 16 km/year). The same authors also recorded that, in 1972, the invaded area increased by 3000 km^2 to the north, south, and east of the species' former range, reducing the rate of spread to 8 km/year. During 1975 and 1978, rabbits spread slowly to the east

and faster southwards reaching the Aluminé River, Neuquén province. Until 1978, the invaded area was 45,000 km^2 (83–114 individuals/ha; Bonino and Amaya 1984). Afterwards, Bonino and Gader (1987) found that, between 1982 and 1986, rabbits had advanced about 40 km eastwards and southeastwards. This is a dispersal rate of about 10 km/year. Towards the north, in Mendoza, rabbits arrived in the Grande and Malargüe rivers. By 1986, the area of expansion of rabbits covered 50,000 km^2 in Mendoza and Neuquén provinces. According to Bonino and Soriguer (2004), rabbits in Mendoza province occupied 11,000 km^2 in 2003, 77% higher than in 1986. A new update of the distribution of rabbits in this area was performed by Bonino and Soriguer (2009). They found that between 2006 and 2008, dispersal of this species occurred mainly along the banks of the Colorado, Neuquén, and Picún Luefú rivers, generally from east to west. In each case, the dispersal rate was 5 km/year. Furthermore, to the south of their range, rabbits spread 175 km farther than the distribution described in 1986 (dispersal rate: 6–9 km/year). The same authors also noticed the importance of rivers in the spread of rabbits in this region, especially in unfavorable habitats such as semiarid environments. Afterwards, Galende (2014) recorded the presence of rabbits in Nahuel Huapi National Park, 15 km farther south than the last record. Finally, between 2014 and 2015, Guichón et al. (2016) updated the distribution of rabbits in Neuquén province. In contrast to findings by Bonino and Soriguer (2009), they found that the rabbit expanded its range towards east and southeast, including in it the Nahuel Huapi and Lanín National Parks, and the Limay River valley; whereas rabbits moved to the central east region through the Neuquén River. Unlike Bonino and Soriguer (2009), Guichón et al. (2016) indicated absence of rabbits in the northwest of Neuquén province. In 2015, the total invaded area was 58,928 km^2, which means a 32% increase since 2008. Thereby, in this area, we can notice that rabbits are still spreading out using rivers as the main dispersal corridors.

(4) Nabte et al. (2009) recorded a new introduction of rabbits in Estancia La Irma, Chubut province. This ranch used rabbits as food supply, and several individuals were released in 2001. The authors confirmed this species' expansion to neighboring ranches.

(5) In 1985, rabbits were detected in Río Turbio city, in the southwest of Santa Cruz province, probably coming from Puerto Natales, Chile, where several animals were released in 1970 (Bonino and Soriguer 2009). Apparently, the population of Río Turbio is still restricted to that area.

9.4 Main Contributions to Ecology and Impacts in Argentina

In addition to the information described in the previous section about the distribution and expansion of rabbits in Argentina, from the 1980s onwards, there has been an increase in research on rabbits aiming to provide information about its diet,

Table 9.2 Main literature published on European rabbit in Argentina: invaded range, ecological traits, impacts, and management

Invaded range	Ecological traits	Impacts	Management	References
Northern Patagonia	Distribution range expansion			Guichón et al. (2016), Galende (2014), Cuevas et al. (2011), Bonino and Soriguer (2009), Bonino and Soriguer (2004), Navas (1987), Bonino and Gader (1987), Bonino and Amaya (1984), Howard and Amaya (1975)
	Body parameters			Donadio et al. (2005), Bonino and Donadio (2010)
	Genetics			Bonino and Soriguer (2008)
	Diet			Bonino and Borrelli (2006)
		competition for resources		Bonino (2006), Galende (2014) Bobadilla et al. (2020)
		Exotic prey		Barbar et al. (2018), Barbar et al. (2016), Novaro et al. (2004), Donázar et al. (1997), Hiraldo et al. (1995)
		Plant community		Veblen et al. (2004)
Southern Patagonia	Distribution range expansion			Nabte et al. (2009), Udrizar Sauthier et al. (2017)
	Body parameters			Amaya and Bonino (1981)
	Genetics			Bonino and Soriguer (2008)
	Diet	Cultural		Amaya and Bonino (1981), Valenzuela et al. (2013)
			Disease (myxomatosis)	Aparicio et al. (2006), Aparicio et al. (2004)
San Juan province	Diet			Laspina et al. (2013)

reproduction, morphology, diseases (myxomatosis) and competition with other herbivores. A synthesis of research on the European rabbit in Argentina is presented in Table 9.2.

9.4.1 Ecological Traits

In Argentina, the only published study addressing some aspects of body parameters and sexual dimorphism of the European rabbit in Patagonia was conducted in the Andean region of Neuquén province (Bonino and Donadío 2010). The study showed a clear sexual dimorphism between adult females and adult males, with females being significantly heavier and larger than males. Additionally, rabbits from Argentina were significantly heavier than rabbits inhabiting both their original (Europe) and invaded ranges (Australia and Chile). The authors suggest that low predation rates and/or the differential expression of genetic traits could explain the observed pattern. These results are consistent with the large body size and highly variable coat coloration observed in Argentina's rabbits (Bonino and Soriguer 2008). In this sense, a study of mitochondrial DNA reveals that the foundational stock of the populations in Patagonia comes from the domestic rabbit *O. cuniculus* (Bonino and Soriguer 2008). However, deciding what factor explains the observed pattern will require additional studies. On the other hand, Donadio et al. (2005) presented a simple method to estimate body mass and relative age of European rabbits that will yield new insights on prey selection patterns and on the feeding ecology of native predators.

Various studies have addressed the botanical composition and seasonal variations in the diet of European rabbits in Argentina. In the central Andean region of Neuquén province, grasses represented the main basis of the diet throughout the year (46%), where *Poa pratensis* and *Festuca pallescens* were the most consumed species (Bonino and Borelli 2006). Graminoids were the second most important group (28%), with *Juncus balticus* and *Carex gayana* as major nutritional items. Forbs had moderate participation in the spring and summer diets, whereas shrubs and tree species were relatively important during the winter (Bonino and Borelli 2006). According to this study, the rabbit proved to be mainly a grazer with wet meadows or "mallines" being its main feeding areas, although its use of space varies according to the seasons of the year. Amaya and Bonino (1981) found similar results for Tierra del Fuego province. These authors recorded grasses as the most important food in the diet, followed by graminoid plants (*Cyperaceae* and *Juncaceae*). The genus *Poa* spp. was the most important item within the first group, and *Carex* spp. within the second (Amaya and Bonino 1981). In San Juan province, an arid environment, grasses and shrubs were the most consumed food items in both wet and dry seasons. In this environment, the European rabbit did not consume the most abundant plant categories and species (Laspina et al. 2013). In conclusion, in Argentina, rabbits feed mainly on grasses, but when these are scarce, they consume woody vegetation, behaving like opportunist grazers by adjusting their diet to the available food supply.

There are no specific studies published in Argentina addressing habitat use by rabbits. The available data show that, in the western part of the distribution range in Neuquén province, the European rabbit occupies sub-Antarctic forests and grasslands. However, in the eastern sector, in a semi-desert environment with scrub formations, the rabbit presents the most irregular distributional pattern and is found in places alongside rivers and small streams (Bonino and Soriguer 2009). This was also observed for an arid environment in Mendoza and San Juan provinces, where distribution of the rabbit is restricted to wetlands or places with streams or moister sites (Laspina et al. 2013; Cuevas et al. 2011). Similar results were found in the south of Mendoza where the rabbit positively selects wetlands or riparian habitats

(Bobadilla et al. unpublished data). An important point is to consider watercourses as spreading routes for this invasive species, especially in arid habitats (Bonino and Soriguer 2004).

9.4.2 Impacts

Just like on the global scale, diet studies in the northwest of Patagonia showed food competition with domestic livestock, increased grazing pressure, and, accordingly, a decrease in the carrying capacity of agricultural land (Bonino 2006; Williams et al. 1995; Travers et al. 2017). Studies conducted in native forests of *Nothofagus pumilio* in Argentina's Patagonia showed that European rabbit's browsing can prevent regeneration of these forests (Veblen et al. 2004, and references therein). On the other hand, there is trophic overlap with a native herbivore, the mountain viscacha (*Lagidium viscacia*), and the rabbit represents a threat to its colonies in situations of food scarcity (Galende 2014). Rabbits are prey for both native and exotic predators in Argentina and could indirectly contribute to the decline of native fauna by becoming a subsidy resource for predators when native prey is scarce (Valenzuela et al. 2013). For example, in the arid Patagonian landscapes, the European hare (*Lepus europaeus*) and rabbit account for 55% of the prey biomass of the Great Horned owl (*Bubo magellanicus*) and for a 58% frequency in the diet of the Gray Buzzard-eagle (*Geranoaetus melanoleucus*) (Hiraldo et al. 1995; Donázar et al. 1997). This finding was consistent with current studies confirming that these exotic lagomorphs account for a high percentage of the biomass consumed by native carnivores in South America (Novaro et al. 2004; Barbar et al. 2016). Besides, the European rabbit may play a role in facilitating establishment of exotic predators (Barbar and Lambertucci 2018). Finally, rabbits have cultural impacts given their preference for digging their burrows on archeological sites along the coastline of the Beagle Channel (Valenzuela et al. 2013, and references therein).

9.4.3 Management

Myxomatosis and rabbit hemorrhagic disease are the major viral diseases in the Iberian Peninsula and significantly affect natural populations of European rabbits (Pacios-Palma et al. 2016). Myxomatosis is a lethal disease for the European rabbit, and even though it is vectored by fleas (*Spilopsyllus cuniculi*) and mosquitoes (*Anopheles annulipes*, *Culex annulirostris*), it can also be transmitted between rabbits by respiratory tract (Fenner and Ross 1994). Given this fact, this disease can lead to decline and extinction of wild populations. This virus has been used as biological control of exotic rabbit populations in Australia and Europe (Kerr 2012). By 1954, the myxoma virus, brought from Brazil, was introduced in Chile and succeeded in bringing rabbits to low population levels on Tierra del Fuego Island

(Jaksic and Yáñez 1983). In Argentina, its use is not allowed by the National Food Safety and Quality Service (Senasa) (Bonino and Amaya 1984). However, there are studies on the dynamics of the myxoma-*Oryctolagus* system which provide guidelines determining potential strategies for control of European rabbits in Argentina (Aparicio et al. 2004; Aparicio et al. 2006). These studies showed that the usual strategy, consisting in introducing highly virulent strains into rabbit populations, might not be the optimal, whereas a control strategy based on introduction of intermediate virulence strains can be much more effective.

9.5 What happens with European Rabbits in Argentina?

9.5.1 Anomalous Situation in Argentina's Northern Patagonia

European rabbits have successfully established in the wild in central Chile. From there, they slowly expanded their distribution across the Andes into Neuquén and Mendoza provinces (see above). Thus, the rate of spread for Neuquén and Mendoza varies between 2 and 10 km/year, depending on the environmental conditions of each valley. The lowest rate (2 km/year) was recorded in the western area with mountainous topography and forest vegetation, while the highest rate (10 km/year) was recorded in the eastern part with flatter topography and along watercourses (Bonino and Gader 1987; Bonino and Soriguer 2004). The dispersal rate in Australia varies between 15 km/year in denser woodlands of the eastern and southern regions and 300 km/year along the drainage channels in the Simpson Desert (Myers et al. 1994). Henzell et al. (2008) consider that there exists an anomalous situation for European rabbits in South America, particularly in Argentina's Northern Patagonia, where there is a low rate of dispersal compared to Australia. According to these authors, this anomalous situation may have arisen as a result of several factors: (1) Possible competition between rabbits and South America's diverse caviomorph rodent fauna (including species similar to rabbits in size, dietary preferences, and burrowing habits) and presence of native predators adapted to catching those caviomorph rodents; (2) potential competition with European hares (*Lepus europaeus*) because both species might occupy most of the other's habitat in its absence; (3) presence in South America of an undiscovered Biological Control Agent in non-lagomorphs that can cross the species barrier into European rabbits (e.g., a coccidian species was recently described in domestic rabbits in Argentina); (4) high probability that the origin of wild rabbits in South America was domestic (feral populations of domestic rabbits did not irrupt dramatically); and (5) high prevalence of C4 grass species, disadvantageous to an herbivorous small mammalian *r*-strategist like the rabbit (C3 grasses predominate in Mediterranean Europe and Australia) (Henzell et al. 2008). However, little is known about support for any of these possible explanations. Updated reports on expansion of the invaded area in Neuquén province showed that European rabbits are the invasive mammals presenting the largest area of occupation at this site, showing an active process of geographical expansion (see Fig. 9.1 and related text) (Guichón et al. 2016).

9.5.2 *Successful Establishment in the Primary Source*

When propagules are transported to a novel range, there could be a match between their native habitat and at least one habitat in the area of introduction – habitat compatibility – that enables their survival at the initial stages of invasion (Steinmaus 2011). The abundance of an introduced organism or its geographical extent in the invaded range may be influenced by a combination of factors in the initial establishment phases (e.g., propagule pressure, minimum residence time, species ecological requirements) (Thuiller et al. 2006). In this way, Sax (2001) showed that the invaded range of an introduced species is determined by the same kind of ecological forces as those limiting the native range of such species. Particularly, alien mammals display good climate matching, that is to say, occupy similar ecoregions to their native ranges (Novillo and Ojeda 2008). A good example is the establishment of a European rabbit population in central Chile, where climate matches that of its native range (Mediterranean-type climate) (Fig. 9.2). This population expanded its geographic distribution both to the north and south of central Chile towards new habitat types. Their northernmost distribution boundary is Quebrada Honda Bay (28° S latitude, tropical ecoregion/subtropical steppe), and their southernmost one is Paillaco town (40° S latitude, subtropical ecoregion) (Jaksic et al. 2002). When the rabbit population expanded its range towards Argentina (see Fig. 9.1), it initially established two

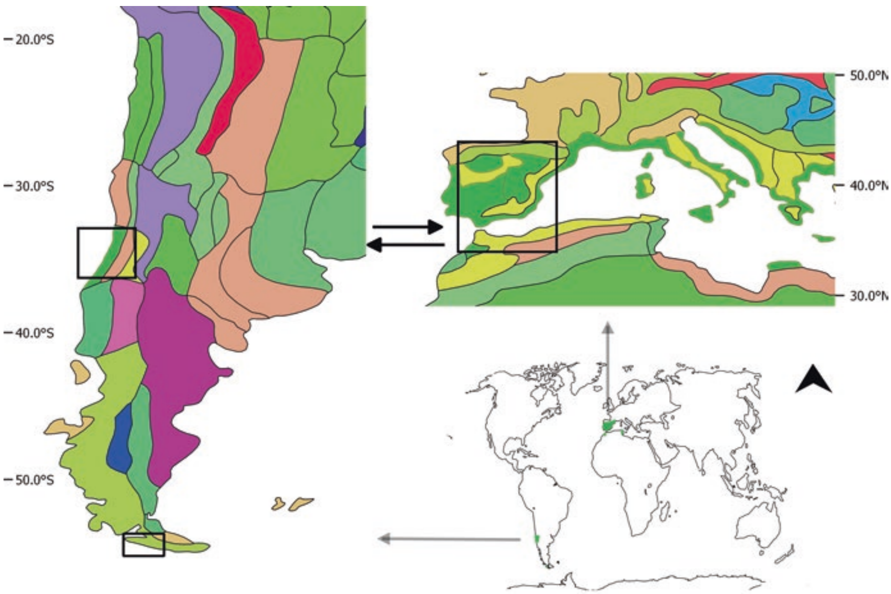

Fig. 9.2 Representation of native (Iberian Peninsula, south of France and north of Africa) and invaded (central Chile) ecoregions showing their good climate matching (Mediterranean-type climate)

different environments: one to the west where rainy Mediterranean climate prevails and another one to the east with semiarid Mediterranean characteristics (Bonino and Amaya 1984). Therefore, the main invaded range in Argentina also shows a climate regime similar to that of the native range (Fig. 9.2). A separate introduction of European rabbits occurred on Tierra del Fuego Island, despite this region lying at a higher latitude (54° S), and presents a cold, Steppe-like climate (Fig. 9.2). According to Flux (1994), the limiting factors appear to be snow cover depth at high latitudes and access to either water or green vegetation at low latitudes. As in its native range, in central Chile and Tierra del Fuego Island, growing seasons are cool and C3 plants predominate. In Australia, the success of European rabbits is believed to be in part the result of replacement of low-quality C4 plants by high-quality annual C3 plants (Henzell et al. 2008). These characteristics are repeated throughout Argentina's Patagonia, and, in this sense, the whole area is suitable for invasion by this species (Bonino and Amaya 1984).

9.6 Prospects for Research

The European rabbit probably is one of the most studied mammals, mainly in the Iberian Peninsula, England, Australia, and New Zealand. This is because, on the one hand, it is a species at conservation risk within its native range and, on the other hand, it is one of the most harmful invasive mammals. Currently, the flow of information is reciprocal between research for the rabbit's conservation and for its control. Thus, it is an interesting and very suitable organism that could be considered both as a model of study to demonstrate the wide range of complex effects that an introduced mammalian species may exert on ecosystems where it has been introduced and as a subject of conservation efforts in its native range (Lees and Bell 2008). However, currently, there are still information gaps in Argentina about its use of habitat, population trend, genetics, behavior, and impacts. Even more, there are no published works about parasitological and zoonotic characteristics, management strategies, or potential social conflicts, and knowledge is lacking about its introduction history and expansion (Bobadilla et al., unpublished manuscript) (Table 9.2). It is important to conduct more fundamental studies of its natural history and autecology, essential to answer complex ecological questions, anticipate their responses to invaded environments, and generate efficient protocols for its monitoring and management. Although there are some studies assessing niche overlap with other exotic herbivores, it is necessary to quantify more ecological impacts such as possible changes in abundance of native species (competition for resources, enhancing predator populations) and modification of vegetation and soil structure, which reduce pastoral productivity and eventually increase landscape degradation. Another of the associated problems, unknown in Argentina, is the possible risk of zoonosis, because rabbits are hosts of various parasites and can also act as natural reservoirs of infectious agents of some diseases (Shaughnessy et al. 2013; Ryll et al. 2018). In conclusion, future studies should be aimed to better understand the invasiveness of the

European rabbit in Argentina and should determine what key factors could limit or favor its expansion. Furthermore, it is important to quantify and categorize its impacts to improve management strategies and risk assessments.

References

Amaya J, Bonino NT (1981) El conejo silvestre europeo (*Oryctolagus cuniculus*) en Tierra del Fuego. Revista de Información sobre Investigación y Desarrollo Agropecuario 388:14–31

Aparicio JP, Solari HG, Bonino NA (2004) Competition and coexistence in host-parasite systems: the myxomatosis case. Popul Ecol 46:71–85

Aparicio JP, Solari HG, Bonino NA (2006) Perspectivas teóricas sobre la dinámica de la mixomatosis con aplicaciones en control biológico. Ecol Austral 16:15–28

Barbar F, Hiraldo F, Lambertucci SA (2016) Medium-sized exotic prey create novel food webs: the case of predators and scavengers consuming lagomorphs. PeerJ 4:e2273

Barbar F, Lambertucci SA (2018) The roles of leporid species that have been translocated: a review of their ecosystem effects as native and exotic species. Mammal Rev 48:245–260

Bobadilla SY, Marchetta A, Dacar MA, Ojeda RA, Cuevas MF (2020). Food habits of European rabbit and its role as seed dispersal of two Mosqueta roses: Facilitation among non-native species in a semiarid protected area of Argentina? Biological Invasions 22:1565–1571

Bonino NA, Amaya J (1984) Distribución geográfica, perjuicios y control del conejo silvestre europeo *Oryctolagus cuniculus* (L.) en la República Argentina. Revista de Información sobre Investigación y Desarrollo Agropecuario 429:25–50

Bonino NA, Gader R (1987) Expansión del conejo silvestre europeo (*Oryctolagus cuniculus* L.) en la República Argentina y perspectivas futuras. Anales Museo Historia Natural de Valparaíso 18:157–162

Bonino NA, Soriguer RC (2004) Distribución actual y dispersión del conejo europeo (*Oryctolagus cuniculus*) en Mendoza (Argentina). Mastozoología Neotropical 11:237–241

Bonino NA, Borrelli L (2006) Variación estacional de la dieta del conejo silvestre europeo (*Oryctolagus cuniculus*) en la región andina de Neuquén, Argentina. Ecol Austral 16:7–13

Bonino NA (2006) Interacción trófica entre el conejo silvestre europeo y el ganado doméstico en el noroeste de la Patagonia Argentina. Ecol Austral 16:135–142

Bonino NA, Soriguer R (2008) Genetic lineages of feral populations of the *Oryctolagus cuniculus* (Leporidae, Lagomorpha) in Argentina. Mammalia 72:355–357

Bonino NA, Soriguer R (2009) The invasion of Argentina by the European wild rabbit *Oryctolagus cuniculus*. Mammal Rev 39:159–166

Bonino NA, Donadio E (2010) Parámetros corporales y dimorfismo sexual en el conejo silvestre europeo (*Oryctolagus cuniculus*) introducido en Argentina. Mastozoología Neotropical 17:123–127

Bridges EL (1949) Uttermost part of the Earth. E. P. Dutton and Co., New York

Courchamp F, Langlais M, Sugihara G (2000) Rabbits killing birds: modelling the hyperpredation process. J Anim Ecol 69:154–164

Courchamp F, Chapuis JL, Pascal M (2003) Mammal invaders on islands: impact, control and control impact. Biol Rev 78:347–383

Crooks JA (2002) Characterizing ecosystem-level consequences of biological invasions: the role of ecosystem engineers. Oikos 97:153–166

Cuevas MF, Chillo V, Marchetta A, Ojeda RA (2011) Mammalia, Lagomorpha, Leporidae, *Oryctolagus cuniculus* Linnaeus, 1758: New record and its potential dispersal corridors for northern Mendoza, Argentina. Check List 7:565–566

Davey C, Sinclair ARE, Pech RP, Arthur AD, Krebs CJ, Newsome AE, Hik D, Molsher R, Allcock K (2006) Do exotic vertebrates structure the biota of Australia? An experimental test in New South Wales. Ecosystems 9:992–1008

Delibes-Mateos M, Delibes M, Ferreras P, Villafuerte R (2008) Key role of European rabbits in the conservation of the Western Mediterranean basin hotspot. Conserv Biol 22:1106–1117

Delibes R, Delibes-Mateos M (2015) Linking historical ecology and invasion biology: some lessons from European rabbit introductions into the new world before the nineteenth century. Biol Invasions 17:2505–2515

Donadio E, Pauli JN, Bonino NA (2005) A method to estimate body mass and relative age of exotic lagomorphs in the southern Neotropics. Acta Theriol 50:81–89

Donázar JA, Travaini A, Ceballos O, Delibes M, Hiraldo F (1997) Food habits of the great horned owl in northwestern Argentine Patagonia: the role of introduced lagomorphs. J Raptor Res 31:364–369

Eldridge DJ, Myers CA (2001) The impact of warrens of the European rabbit (*Oryctolagus cuniculus* L.) on soil and ecological processes in a semi-arid Australian woodland. J Arid Environ 47:325–337

Eldridge DJ, Koen TB (2008) Formation of nutrient-poor soil patches in a semi-arid woodland by the European rabbit (*Oryctolagus cuniculus* L.). Austral Ecol 33:88–98

Fenner F, Ross J (1994) Myxomatosis. In: Thompson HV, King CM (eds) The European rabbits, the history and biology of a successful colonizer. Oxford University Press, Oxford, pp 205–240

Flux JEC, Fullagar PJ (1992) World distribution of the Rabbit *Oryctolagus cuniculus* on islands. Mammal Rev 22:151–205

Flux JEC (1994) World distribution. In: Thompson HV, King CM (eds) The European rabbit: the history of a successful colonizer. Oxford University Press, Oxford, pp 8–21

Galende GI (2014) *Oryctolagus cuniculus* Linnaeus, 1758 (Mammalia: Lagomorpha: Leporidae): new record in the Nahuel Huapi National Park, Patagonia, Argentina. Check List 10:1179–1183

Gálvez-Bravo L, Belliure J, Rebollo S (2008) European rabbits as ecosystem engineers: warrens increase lizard density and diversity. Biodivers Conserv 18:869–885

Guichón ML, Monteverde M, Piudo L, Sanguinetti J, Di Martino S (2016) Mamíferos introducidos en la provincia de Neuquén: estado actual y prioridades de manejo. Mastozoología Neotropical 23:255–265

Henzell RP, Cooke BD, Mutze GJ (2008) The future biological control of pest populations of European rabbits, *Oryctolagus cuniculus*. Wildl Res 35:633–650

Hiraldo F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Funes M (1995) Breeding biology of a grey eagle-buzzard population in Patagonia. The Wilson Bulletin 107:675–685

Holmgren M (2002) Exotic herbivores as drivers of plant invasion and switch to ecosystem alternative states. Biol Invasions 4:25–33

Howard WE, Amaya JN (1975) European rabbits invades western Argentina. J Wildl Manag 39:757–761

Jaksic FM, Yáñez J (1983) Rabbit and fox introductions in Tierra del Fuego: history and assessment of the attempts at biological control of the rabbit infestation. Biol Conserv 26:367–374

Jaksic FM (1998) Vertebrate invaders and their ecological impacts in Chile. Biodivers Conserv 7:1427–1445

Jaksic FM, Iriarte JA, Jiménez JE, Martínez DR (2002) Invaders without frontiers: cross-border invasions of exotic mammals. Biol Invasions 4:157–173

Kerr PJ (2012) Myxomatosis in Australia and Europe: a model for emerging infectious diseases. Antiviral Res 93:387–415

Mack RN, Simberloff D, Lonsdale MW, Evans H, Clout M, Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. Ecol Appl 10:689–710

Myers K, Parer I, Wood D, Cooke BD (1994) The rabbit in Australia. In: Thompson HV, King CM (eds) The European rabbit: the history of a successful colonizer. Oxford University Press, Oxford, pp 108–157

Nabte MJ, Saba SL, Monjeau A (2009) Mamíferos terrestres de la Península Valdés: lista sistemática comentada. Mastozoología Neotropical 16:109–120

Navas JA (1987) Los vertebrados exóticos introducidos en la Argentina. Revista del Museo Argentino de Ciencias Naturales, Serie Zoología XIV, pp 7–38

Novaro AJ, Funes MC, Jiménez JE (2004) Patagonian foxes selection for introduced prey and conservation of culpeo and chilla foxes in Patagonia. In: Macdonald DW, Sillero-Zubiri C (eds) The biology and conservation of wild canids. Oxford University Press Canada, Don Mills, pp 239–250

Novillo A, Ojeda RA (2008) The exotic mammals of Argentina. Biol Invasions 10:1333–1334

Laspina CA, Ortiz SG, Reus ML, De Los Ríos C (2013) Dieta de *Oryctolagus cuniculus* (conejo silvestre europeo) y disponibilidad de recursos tróficos en el Parque Nacional El Leoncito (San Juan, Argentina). Multequina (Argentina) 22:37–44

Lees AC, Bell DJ (2008) A conservation paradox for the 21st century: The European wild rabbit *Oryctolagus cuniculus*, an invasive alien and an endangered native species. Mammal Rev 38:304–320

Lowe S, Browne M, Boudjelas S, De Poorter M (2000) 100 of the world's worst invasive alien species: A selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), Auckland

Pacios-Palma I, Santoro S, Bertó-Moran A, Moreno S, Rouco C (2016) Effects of myxoma virus and rabbit hemorrhagic disease virus on the physiological condition of wild European rabbits: Is blood biochemistry a useful monitoring tool? Res Vet Sci 109:129–134

Ryll R, Eiden M, Heuser E, Weinhardt M, Ziege M, Höper D, Groschup MH, Heckel G, Johne R, Ulrich RG, R. G. (2018) Hepatitis E virus in feral rabbits along a rural-urban transect in Central Germany. Infect Genet Evol 61:155–159

Sax DF (2001) Latitudinal gradients and geographic ranges of exotic species: implications for biogeography. J Biogeogr 28:139–150

Shaughnessy LJ, Smith LA, Evans J, Anderson D, Caldow G, Marion G, Low JC, Hutchings MR (2013) High prevalence of paratuberculosis in rabbits is associated with difficulties in controlling the disease in cattle. Vet J 198:267–270

Steinmaus S (2011) Habitat compatibility. In: Simberloff D, Rejmánek M (eds) Encyclopedia of biological invasions. University of California Press, Berkeley/Los Angeles, pp 305–309

Thompson HV, King CM (1994) The rabbit in Britain. In: The European rabbit: the history of a successful colonizer. Oxford University Press, Oxford, pp 64–107

Thuiller W, Richardson DM, Rouget M, Proches S, Wilson JR (2006) Interactions between environment, species traits, and human uses describe patterns of plant invasions. Ecology 87:1755–1769

Udrizar Sauthier DE, Pazos GE, Cheli GH, Coronato F (2017) Mamíferos terrestres en islas del Atlántico Sudoccidental, Patagonia, Argentina. Mastozoología Neotropical 24:251–256

Valenzuela AE, Anderson CB, Fasola L, Cabello JL (2013) Linking invasive exotic vertebrates and their ecosystem impacts in Tierra del Fuego to test theory and determine action. Acta Oecol 54:110–118

Vázquez DP (2002) Multiple effects of introduced mammalian herbivores in a temperate forest. Biol Invasions 4:175–191

Veblen TT, Kitzberger T, Villalba R (2004) Nuevos paradigmas en ecología y su influencia sobre el conocimiento de la dinámica de los bosques del sur de Argentina y Chile. In: Arturi MF, Frangi JL, Goya JF (eds) Ecología y Manejo de los Bosques de Argentina. Editorial de la Universidad Nacional de La Plata, La Plata, Argentina, p 19

Williams CK, Parer I, Coman BJ, Burley J, Braysher ML (1995) Managing vertebrate pests: rabbits. Australian Government Publishing Service, Canberra