

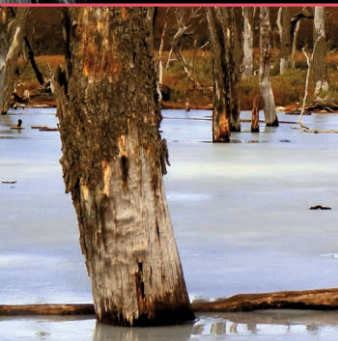
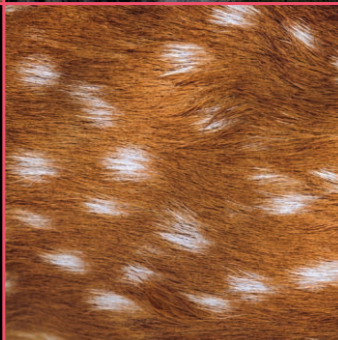


SAREM Series A  
Mammalogical Research  
Investigaciones Mastozoológicas

VOLUME 3

# INTRODUCED INVASIVE MAMMALS OF ARGENTINA

## MAMÍFEROS INTRODUCIDOS INVASORES DE ARGENTINA



Alejandro E. J. Valenzuela, Christopher B. Anderson, Sebastián A. Ballari and Ricardo A. Ojeda, EDITORS

**The Argentine Society for the Study of Mammals** (Sociedad Argentina para el Estudio de los Mamíferos – SAREM) was created in 1983, and currently has about 300 members from several countries. SAREM is an interdisciplinary society of natural sciences professionals whose main goals are the promotion of scientific and technical research, the consolidation of national collections and research centers, and the publication and diffusion of research on living and/or extinct mammals. SAREM has organized scientific meetings for mammal researchers since 1994, publishes the journals *Mastozoología Neotropical* and *Notas sobre Mamíferos Sudamericanos*, and has edited books on the systematics, distribution and conservation of the mammals of southern South America, including *Libro Rojo de los mamíferos amenazados de la Argentina* (first ed. 2000, second ed. 2012) and *Mamíferos de Argentina. Sistemática y distribución* (2006), as well as contributing to the *Libro Rojo de los mamíferos y aves amenazados de la Argentina* (currently out of print).

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**SAREM Series A**  
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Introduced invasive species are a major driver of local to global environmental change, including important negative impacts on biodiversity, ecosystem processes, economies, health and other social values. At the same time, however, different social actors can hold diverse representations of these species, particularly of introduced invasive mammals (IIMs). Such divergent values and perceptions can lead to conflicts regarding the management of IIMs, but also invite researchers and managers to be reflexive regarding their own work at a more fundamental level. Therefore, it is key that we advance towards a holistic understanding of IIMs and develop strategies to manage them based on solid technical information and plural perspectives regarding their multiple values. Despite a rich history of initiatives in Argentina to study and manage IIMs, until now there has not been an opportunity to assess the state-of-the-art knowledge in our country. This book seeks to provide rigorous, relevant and legitimate information to support research, policymaking and management decisions regarding IIMs in Argentina. With this objective in mind, the book presents a series of chapters selected to highlight priority topics concerning the conceptualization and implementation of IIM research and management. Then, fact sheets are provided for the different IIMs found in Argentina. Finally, beyond the realm of academic inquiry, the timing of this publication is ideal to re-enforce policy and decision-making, such as the recently approved National Invasive Exotic Species Strategy, which seeks to implement actions and enhance institutional capacities related to invasive species management in Argentina, and the Convention on Biological Diversity's new Global Biodiversity Framework, which also addresses biological invasions as part of broader efforts to attain the 2050 Vision for Living in Harmony with Nature.

Dr. Alejandro E.J. Valenzuela  
Dr. Christopher B. Anderson  
Editors, Vol. III SAREM Series A

# CONTENTS

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LIST OF REVIEWERS.....	VII
FOREWORD.....	IX–X
DANIEL SIMBERLOFF	
1 INTRODUCED AND INVASIVE MAMMALS: CONCEPTUAL AND HISTORICAL PERSPECTIVES FOR ARGENTINA.....	1–30
S. YASMIN BOBADILLA, ANDREA DEL PILAR TARQUINO-CARBONELL AND RICARDO A. OJEDA	
2 RECONCEIVING BIOLOGICAL INVASIONS AS A SOCIO-ECOLOGICAL PHENOMENON USING THE CASE STUDY OF BEAVERS IN PATAGONIA.....	31–51
CHRISTOPHER B. ANDERSON AND J. CRISTOBAL PIZARRO	
3 CHARISMA AS A KEY ATTRIBUTE FOR THE EXPANSION AND PROTECTION OF SQUIRRELS INTRODUCED TO ARGENTINA.....	53–73
M. LAURA GUICHÓN, MARIELA BORGNA, VERÓNICA BENITEZ AND A. CECILIA GOZZI	
4 HUNTING AS A DRIVER OF MAMMAL INTRODUCTIONS.....	75–93
SEBASTIÁN A. BALLARI, M. NOELIA BARRIOS-GARCÍA, JAVIER SANGUINETTI, HERNÁN PASTORE AND M. FERNANDA CUEVAS	
5 IMPACT OF INTRODUCED INVASIVE HERBIVORES IN PATAGONIAN FORESTS.....	95–110
M. NOELIA BARRIOS-GARCÍA, CAROLINA QUINTERO, YAMILA SASAL, SEBASTIÁN A. BALLARI, AGUSTÍN VITALI AND MARIANO A. RODRIGUEZ-CABAL	
6 MANAGEMENT OF FERAL HORSES AS INVASIVE MAMMALS: BIODIVERSITY CONSERVATION VERSUS CULTURE?.....	111–126
ALBERTO L. SCOROLLI	
7 PROGRESS OF BIOLOGICAL INVASION GENETICS AND THE MANAGEMENT OF INVASIVE MAMMALS IN ARGENTINA.....	127–141
MARTA S. LIZARRALDE, MARIANA FASANELLA, SEBASTIÁN POLJAK AND MAGALI GABRIELLI	
8 DISEASE RISKS FROM INTRODUCED MAMMALS.....	143–172
MARCELA M. UHART	
9 EXOTIC SPECIES IN THE FORMAL EDUCATIONAL SPHERE IN ARGENTINA.....	173–191
CLAUDIA M. CAMPOS, GONZALO M. BERMUDEZ, GABRIELA B. DIAZ AND ALFREDO VILCHES	
10 MEDIA REPRESENTATIONS OF INTRODUCED INVASIVE MAMMALS: A COMPARISON BETWEEN TRENDS IN ARGENTINA AND TIERRA DEL FUEGO PROVINCE.....	193–205
VALERIA CAR, NATALIA ADER, CHRISTOPHER B. ANDERSON AND ALEJANDRO E.J. VALENZUELA	
FACT SHEETS ON THE INTRODUCED INVASIVE MAMMALS OF ARGENTINA	
<i>Antilope cervicapra</i>   blackbuck, antílope negro.....	209–213
SEBASTIÁN A. BALLARI	
<i>Axis axis</i>   chital, ciervo axis.....	215–221
JUAN F. TELLARINI, MARIANO L. MERINO AND JAVIER A. PEREIRA	
<i>Bubalus arnee bubalis</i>   wild water buffalo, búfalo asiático.....	223–229
LUCÍA I. RODRÍGUEZ-PLANES, SEBASTIÁN CIRIGNOLI, DIEGO VARELA, MARTA S. KIN AND MARTÍN MONTEVERDE	

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<i>Callosciurus erythraeus</i>   Pallas's squirrel, ardilla de vientre rojo .....	231-242
A. CECILIA GOZZI, VERÓNICA BENITEZ, MARIELA BORGNIA AND M. LAURA GUICHÓN	
<i>Canis lupus familiaris</i>   domestic feral dog, perro doméstico asilvestrado.....	243-248
IAN BARBE, ALFREDO Ñ. CLAVERIE AND ALEJANDRO E.J. VALENZUELA	
<i>Castor canadensis</i>   North American beaver, castor americano .....	249-254
CHRISTOPHER B. ANDERSON AND CATHERINE ROULIER	
<i>Cervus elaphus</i>   red deer, ciervo colorado.....	255-263
JO ANNE M. SMITH-FLUECK AND WERNER T. FLUECK	
<i>ChaetophRACTUS villosus</i>   large hairy armadillo, peludo .....	265-271
SEBASTIÁN POLJAK, MAGALI GABRIELLI, JULIETA SÁNCHEZ AND MARTA S. LIZARRALDE	
Rodentia: Muridae   commensal rodents, roedores comensales .....	273-286
<i>Mus musculus</i>   house mouse, ratón doméstico	
<i>Rattus norvegicus</i>   Norway rat, rata parda o noruega	
<i>Rattus rattus</i>   black rat, rata negra o de los tejados	
REGINO CAVIA AND ISABEL E. GÓMEZ VILLAFañE	
<i>Dama dama</i>   fallow deer, ciervo dama .....	287-291
M. NOELIA BARRIOS-GARCIA	
<i>Felis sylvestris catus</i>   domestic feral cat, gato doméstico asilvestrado.....	293-299
IAN BARBE, ALFREDO Ñ. CLAVERIE AND ALEJANDRO E.J. VALENZUELA	
Feral livestock, ganado cimarrón .....	301-309
<i>Equus ferus caballus</i>   feral horse, caballo cimarrón	
<i>Equus africanus asinus</i>   feral donkey, burro orejano	
<i>Bos primigenius taurus</i>   feral cattle, vaca	
<i>Capra aegagrus hircus</i>   feral goat, cabra	
ALBERTO L. SCOROLLI	
Lagomorpha   European hare and rabbit, liebre y conejo europeos .....	311-317
<i>Lepus europaeus</i>   European hare, liebre europea	
<i>Oryctolagus cuniculus</i>   European rabbit, conejo europeo o de Castilla	
ALEJANDRO E.J. VALENZUELA	
<i>Lycalopex gymnocercus</i>   Pampa fox, zorro gris.....	319-322
ALEJANDRO E.J. VALENZUELA	
<i>Neogale vison</i>   American mink, visón americano .....	323-328
ALFREDO Ñ. CLAVERIE, IAN BARBE, L. ALEJANDRO VILLAGRA AND ALEJANDRO E.J. VALENZUELA	
<i>Ondatra zibethicus</i>   muskrat, rata almizclera.....	329-333
GUILLERMO A. DEFERRARI	
<i>Sus scrofa</i>   wild boar, jabalí .....	335-340
M. FERNANDA CUEVAS	

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## FOREWORD

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Biological invasions by introduced species are one of the great changes rapidly transforming the globe today, with innumerable impacts on economics, human health, ecosystem services, and biodiversity. Mammals are among the most impactful of invasive species, transmitting diseases to humans, livestock, and native animals, trampling native grasslands, voraciously devouring vegetation from groundcover to saplings of forest trees, fouling water, causing erosion, and preying on and outcompeting native animals. They were among the first species humans introduced worldwide and in Argentina, both deliberately (*e.g.*, livestock) and inadvertently (*e.g.*, rats and mice). They have been introduced for sport (*e.g.*, deer, boar) and companionship (*e.g.*, cats, dogs), or simply as attractive ornamentals (*e.g.*, squirrels). Some that are meant to be kept in captivity, such as cats, dogs, and squirrels, escape and establish feral populations.

Argentina looms large in the history of biological invasions by introduced mammals. The earliest permanent European settlers of Buenos Aires in 1580 discovered huge herds of feral horses already on the pampas, and soon after, Vázquez de Espinoza described feral horses in Tucumán that were “in such numbers that they cover the face of the earth...”. Many sheep were in Tucumán as well at that time, and of course later sheep were enormously numerous in Patagonia, effecting huge changes in the vegetation and driving land degradation and desertification to this day. When Charles Darwin visited the La Plata region in 1832 during the voyage of the *Beagle*, he reported that “...countless herds of horses, cattle, and sheep, not only have altered the whole aspect of the vegetation, but they have almost banished the guanaco, deer and ostrich. Numberless other changes must likewise have taken place; the wild pig in some parts probably replaces the peccari; packs of wild dogs may be heard howling on the wooded banks of the less-frequented streams; and the common cat, altered into a large and fierce animal, inhabits rocky hills.”

Approximately 40 mammals have been introduced to South America, of which 25–30 have established populations; most of these are in the Southern Cone. In Argentina, I count 23 successfully introduced mammal species, including feral cats, dogs, and cows. Many, such as rats, rabbits, boar, and goats, are widely distributed around the world. By contrast, the hairy armadillo has been introduced nowhere else but from the mainland of Patagonia to Tierra del Fuego Island. Strikingly, except for the rats and house mouse, all these mammals were brought to Argentina deliberately; this is very different from, say, introduced insects. A few of these invasive mammals, like the squirrel, were not intended to be released, but I hesitate to term such invaders truly “accidental,” because the people who brought them should have realized that escapes or later releases were almost inevitable. Of course, almost all of these mammals were introduced before the late twentieth century, which was when most scientists and the public began to recognize the extent and importance of impacts of introduced species. However, the squirrel and armadillo introductions were recent enough that potential impacts should have been foreseen. Things could be worse, of course—mammals deliberately brought to Argentina that either were released, but did not establish persistent populations or have not yet escaped from hunting preserves include reindeer, silver fox, mule deer, African buffalo, white-tailed deer, Père David’s deer, thar, barbary sheep, wisent, mouflon, chamois, and ibex.



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The technology of eradicating introduced invasive mammals has made enormous strides in the last thirty years—at least 31 mammal species have been eradicated from islands worldwide, including relatively large islands like South Georgia. Both Norway and ship rats have been eradicated hundreds of times, and house mice about 100 times. Most large mammals, such as deer and horses, are technologically easier eradication targets—many can simply be tracked and shot, for instance. However, mammals more than any other introduced species pose the complication that many people—especially hunters—simply do not want to eradicate them, and many animal welfare advocates, even those recognizing the damage some invaders cause, object to eradicating them by the only currently feasible means—killing them, humanely if possible. Even rat eradication has been impeded on animal rights/animal welfare grounds, and free-ranging dog and cat populations frequently are seen more as animal welfare issues than as conservation problems to broad sectors of some societies. In Argentina, the problem of implementing feasible eradication programs for invasive mammals is epitomized by the rather schizophrenic attitude taken by the National Parks Administration (Administración de Parques Nacionales—APN) towards red deer. The APN's conservation imperative is supported by the section of Law #22,351 that forbids propagating introduced animals, yet red deer, known to damage native species and ecosystems, are managed in Lanín National Park to foster ongoing hunting, and even to improve the size and quality of the deer for better hunting trophies. Additionally, there is often inconsistent and inadequate funding for managing and eradicating invasive mammals in protected areas, almost always constituting a supervening impediment even when a rational and effective goal is stated.

Argentine scientists have participated heavily in the rapid growth of modern invasion science since its inception in the 1980s, and they and overseas colleagues have conducted substantial research on the biology and impacts of many of the introduced invasive mammals in Argentina, as well as other invasive species. Some of the threats posed by these mammals have even become widely known to the general public in Argentina and beyond—the spread of the beaver from Tierra del Fuego to the mainland has been an international news story. *Introduced Invasive Mammals of Argentina* is therefore an exciting and timely addition to the literature on invasions in southern South America for both the Argentine public (and its political representatives and environmental managers) and scientists worldwide. The many authors assembled for this book explore how these biological invasions happened in the first place, how they spread, what they do to biodiversity, ecosystems, and human enterprises, what has been done about them so far, what can be done about them now, and what might be done with them in the future. The editors and authors are to be congratulated for an excellent exposition of the Argentine part of a growing global phenomenon.

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# 4 | HUNTING AS A DRIVER OF MAMMAL INTRODUCTIONS

## LA CAZA COMO VECTOR DE LA INTRODUCCIÓN DE MAMÍFEROS

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**Abstract.** Hunting is an ancestral human practice to obtain food. However, in recent times, it has become a highly lucrative economic activity and is a potential conservation tool to control populations of introduced invasive species. Ironically, though, hunting is also one of the most important drivers of mammal introductions around the world. Between the 19th and 20th centuries, at least 25 species of mammals from Europe and Asia have been introduced in game reserves in Argentina. After subsequent escapes and translocations, eight species of the introduced mammals now have wild populations outside these game reserves. Many have also become invasive, causing negative impacts to native biodiversity, economic activities and human health. These outcomes show that hunting reserves represent a source of introduced mammals, and that the lack of regulations and compliance with laws on hunting activities in the country is problematic. On the other hand, hunting on public lands, such as national parks, requires combining efforts between scientists and managers to improve legislation and management of these species in protected areas, where financial and organizational constraints may limit the scope and effectiveness of conservation actions. For example, in Argentina, two control programs provide successful experiences of carrying out inter-institutional participation between local residents, scientists and stakeholders: a short time hunting program to control red deer in Parque Nacional Lanín and a long-time hunting program to control wild boar in Parque Nacional El Palmar. Given the multi-faceted social, economic, health and ecological impacts of introduced invasive mammals, it is important to update, apply and reinforce the regulation of hunting activities, as well as consider hunting as a tool for the management of introduced invasive mammals.

**Resumen.** La caza es una práctica humana ancestral que se originó para buscar alimento, pero que en tiempos recientes se ha convertido en una actividad altamente lucrativa, también utilizada para

reducir o controlar poblaciones de animales plaga, e incluso con fines de conservación para proteger especies en peligro de extinción. La caza, ya sea para obtener alimento o como actividad cinegética, es uno de los motivos más importantes en todo el mundo de la introducción de mamíferos fuera de su rango nativo. Principalmente desde el inicio del siglo XV con las incursiones desde Europa para explorar y descubrir nuevas tierras, muchos animales de trabajo (p.ej. caballos) y cría (p.ej. cerdos) fueron transportados e introducidos a nuevas regiones alrededor de todo el mundo. Más recientemente, la actividad cinegética se ha convertido en uno de los vectores más importantes de la introducción de mamíferos en todos los continentes. Esto ha ocurrido en Sudamérica entre principios del siglo XIX y finales del siglo XX, y específicamente en Argentina donde al menos 25 especies de mamíferos han sido introducidas, principalmente desde Europa y Asia.

Si bien estos mamíferos fueron destinados inicialmente a condiciones confinadas en cotos de caza, campos o reservas privadas, los posteriores escapes y translocaciones de animales han provocado que actualmente Argentina cuente con ocho especies de mamíferos introducidos con interés cinegético (antílope negro: *Antilope cervicapra*, ciervo axis: *Axis axis*, búfalo de agua: *Bubalus arnee bubalis*, ciervo colorado: *Cervus elaphus*, ciervo dama: *Dama dama*, liebre europea: *Lepus europaeus*, conejo europeo: *Oryctolagus cuniculus*, y jabalí: *Sus scrofa*) con poblaciones silvestres. Muchas de estas especies son consideradas especies invasoras que provocan impactos sobre la biodiversidad nativa, las actividades productivas y la salud humana.

El elevado número de establecimientos registrados para actividades cinegéticas (>112) distribuidos en gran parte del país, presupone un potencial y latente foco de escape de mamíferos teniendo en cuenta el escaso control y falta de regulaciones en torno a esta actividad. Dichas regulaciones son muy dispares entre los gobiernos provinciales y responden en ocasiones al interés y presiones de diferentes sectores involucrados, por ejemplo, estableciendo cupos al número de animales cazados en especies de mamíferos introducidos consideradas como invasoras (e.g., liebre europea). Muchas de estas especies, a partir de los primeros escapes (intencionales o accidentales) desde establecimientos cinegéticos o campos privados, se han dispersado rápidamente (e.g., jabalí, conejo, liebre), invadiendo nuevos ambientes y alterando la dinámica de estos ecosistemas, afectando así las interacciones entre especies, compitiendo con especies nativas por recursos, reduciendo la cobertura y riqueza de especies vegetales, siendo vectores de enfermedades y facilitando la invasión de otras especies.

La caza deportiva es una actividad permitida en algunos sectores de áreas protegidas de Argentina como los Parques Nacionales Nahuel Huapi y Lanín, donde la caza de ciervo colorado es regulada por la Administración de Parques Nacionales (APN), emitiendo y cobrando los permisos de caza, estableciendo cupos y fechas de caza. En 1986 la APN definió políticas de manejo para que la caza deportiva se desarrolle en el contexto del manejo de poblaciones de ciervo colorado. En este sentido, el gobierno consideró que la caza deportiva puede ser una herramienta aceptable para lograr los objetivos de conservación de la biodiversidad, brindando oportunidades de caza, aplicada en el marco de un manejo y control poblacional.

El manejo poblacional a partir de la aplicación de caza deportiva y caza de control combinadas fue hasta el momento pobremente aplicada, o por cortos periodos de tiempo, principalmente en el Parque Nacional Lanín (PNL), además de en los Parques Nacionales Nahuel Huapi (PNNH), Lihué Calel, Los Alerces y Lago Puelo. Resulta indispensable que, con la vasta información generada sobre la especie y sus impactos en estos últimos años, el manejo del ciervo colorado se lleve a cabo en función de las condiciones de la población (proporción de sexos, rangos de densidad) y en relación con

los objetivos de conservación de la biodiversidad amenazada por esta especie invasora, y no con el foco exclusivo en la caza de trofeos.

La caza, como se destacó anteriormente, también ha sido implementada en tiempos modernos con fines de control y conservación. En el Parque Nacional El Palmar (PNEP), el jabalí y el ciervo axis son dos mamíferos introducidos que han proliferado notablemente en el área provocando impactos negativos sobre la biodiversidad. En particular, la depredación del jabalí sobre renovales de palmera yatay *Butia yatay* (valor de conservación: emblema del área protegida) motivó la implementación de un plan de caza control para los mamíferos invasores en el parque nacional con el objetivo de reducir sus impactos y disminuir sus poblaciones. Formalmente desde 2006 a la actualidad se ha implementado este plan de control, principalmente aplicando caza desde apostaderos elevados utilizando un cebadero. Uno de los aspectos más sobresalientes del plan, además de su continuidad en el tiempo y el éxito reduciendo las poblaciones de jabalí, fue la incorporación de cazadores de las comunidades vecinas, muchos de los cuales anteriormente ingresaban al parque a cazar de manera furtiva. Estos cazadores, ahora controlados y regulados por las autoridades del PNEP, colaboran activamente con el plan de control, reforzando así las relaciones entre los sectores involucrados en el manejo de mamíferos invasores de la región.

La implementación de la caza en tierras públicas es compleja y requiere una articulación entre científicos y gestores para mejorar la legislación y la gestión relacionada con las áreas protegidas y las especies introducidas. Sumado a esto, las capacidades económicas y organizativas de las áreas protegidas muchas veces limitan el logro de un manejo integral y eficiente de los mamíferos invasores con un enfoque cooperativo para perseguir múltiples objetivos que satisfagan a los diferentes actores sociales.

La caza representa a nivel mundial una actividad altamente lucrativa, que ha funcionado como vector de la introducción de mamíferos en todo el mundo. Argentina sufre actualmente las consecuencias de este fenómeno con la invasión e impacto de especies que afectan negativamente la biodiversidad nativa, las actividades productivas y la salud humana. Es importante actualizar, reforzar y aplicar las medidas de control relacionadas con la regulación de las actividades cinegéticas en el país y, por otro lado, considerar seriamente la caza control —delineada con un estricto marco de participación interinstitucional— como una herramienta para la gestión de mamíferos introducidos.

## **Sport hunting in the world and Argentina: socio-economic importance**

Hunting is the practice of searching or lying and waiting for animals with the intent of killing them. It has been used by humans to obtain food since prehistory. However, in Western culture, hunting can also imply a sport or recreational activity. Plus, it has been used to reduce or manage over-abundant animal populations (*i.e.*, “pests” or introduced invasive species) and their impacts (Jeschke and Strayer, 2006; Bengsen and Sparkes, 2016). Globally, hunting now represents an extremely lucrative business, but it also creates incentives for native wildlife conservation. In Africa, hunting can play an important role in the conservation of some endangered species and in the rehabilitation of wildlife areas. For example, income generated by trophy hunting has helped to recover white rhinoceros (*Ceratotherium simum*) populations in South Africa and restore its habitat in Mozambique (Lindsey *et al.*, 2007). However, hunting gets more complex when involving the introduction of species, which represents one of the greatest agents of transformation of native

ecosystems (Simberloff *et al.*, 2013). For example, in North America, successful mammal introductions (and their associated ecological and economical costs) are mostly linked to the hunting industry (Pimentel *et al.*, 2005; Jeschke and Strayer, 2006).

**Table 1.** List of species offered for sport hunting in Argentina, indicating origin (Af= Africa, As= Asia, E= Europe, N= North America, C= Central America, S= South America) and population status at present as free-ranging populations (FRP) or confined populations (CP).

Scientific name	Common name	Origin	FRP	CP
<i>Antilope cervicapra</i>	blackbuck	As	×	×
<i>Axis axis</i>	axis deer	As	×	×
<i>Bubalus arnee bubalis</i>	water buffalo	As	×	×
<i>Capra hircus</i>	wild goat	As		×
<i>Capra ibex</i>	Alpine ibex	E		×
<i>Cervus elaphus</i>	red deer	E, As	×	×
<i>Dama dama</i>	fallow deer	E, As	×	×
<i>Elaphurus davidianus</i>	Père David's deer	As		×
<i>Hemitragus jemlahicus</i>	Himalayan tahr	As		×
<i>Lepus europaeus</i>	European hare	E	×	
<i>Oryctolagus cuniculus</i>	European rabbit	E	×	×
<i>Ovis aries</i>	Texas dall	N		×
<i>Ovis aries</i>	Dorset sheep	E		×
<i>Ovis aries</i>	Scottish blackface sheep	E		×
<i>Ovis aries</i>	Somali sheep	Af		×
<i>Ovis aries orientalis</i>	mouflon sheep	As, E		×
<i>Ovis dalli</i>	Dall's sheep	N		×
<i>Ovis orientalis musimon</i>	European mouflon	E		×
<i>Sus scrofa</i>	wild boar	E, As	×	×

Several reasons explain this observation of successful introductions, including the desirability of mammals as useful in food provisioning, animal husbandry, pets, animal assistance (*e.g.*, for farming), hunting, pest control, and transportation (Long, 2003; Hoddle, 2004; Forsyth *et al.*, 2013; Tedeschi *et al.*, 2021). From all fauna introduction, mammals are the group with most species' introductions at global level (Blackburn *et al.*, 2017). Historically, mammal introductions have been especially prominent in countries where native mammal fauna was non-existent or scarce (*e.g.*, oceanic islands Long, 2003); where the European colonists were unfamiliar with the endemic species to be effectively used in the agricultural or livestock systems (*e.g.*, Australia, Long, 2003, and South America, Ballari *et al.*, 2016); or where there was a perception by colonists that the faunal assemblage needed to be “improved” (Estévez *et al.*, 2015; Archibald *et al.*, 2020).

In southern South America, mammals were mainly introduced for hunting purposes (food or sport hunting) between the late 19th and early 20th centuries (Ballari *et al.*, 2016). Specifically, in Argentina, at least 25 mammal species were brought mainly from Asia and Europe (Table 1). Many of them adapted and invaded most of the country's territory (Navas, 1987; SAyDS and SAREM, 2019). Only a handful species did not prosper and were unsuccessful at invading for various reasons (*e.g.*, lack of adaptation, extreme weather, etc.) (Table 2). Most of these introduced mammals to Argentina are found within private game hunting reserves. There are at least 112 registered shooting or game reserves, most of them located in the central provinces of La Pampa, Córdoba, Neuquén, and Buenos Aires (MJyDH, 2019). These game reserves represent a latent source of potential new escapes or intentional releases that are a pool of future invasive mammals. Therefore, they are also of great importance for invasive species management and planning.

**Table 2.** List of mammals introduced in Argentina for sport hunting that were not successful, indicating origin (Af= Africa, As= Asia, E= Europe, N= North America, C= Central America, S= South America).

Scientific name	Common name	Origin
<i>Ammotragus lervia</i>	aoudad, or Barbary sheep	Af
<i>Bison bonasus</i>	European bison	E
<i>Cervus elaphus canadensis</i>	elk, or wapiti	N, As
<i>Odocoileus virginianus</i>	white-tailed deer	N, C, S
<i>Rangifer tarandus</i>	reindeer, or caribou	E
<i>Rupicapra rupicapra</i>	Alpine chamois	E

Many of the introduced mammals in Argentina are known to cause negative impacts on native ecosystems (Novillo and Ojeda, 2008; Sanguinetti *et al.*, 2014; Valenzuela *et al.*, 2014; Ballari *et al.*, 2016). The reported damages include changes in plant and animal communities due to overgrazing (Relva *et al.*, 2010; Barrios-García *et al.*, 2012), predation, competition (Ballari *et al.*, 2015a), and disease transmission (Flueck and Smith-Flueck, 2012). Below, we will discuss the negative impacts of invasive mammals in more detail, but importantly, the biological consequences of introduced mammals have stimulated scientists and managers to understand their biology and assess their ecological and economic impacts to manage their populations (Pyšek and Richardson, 2010; Simberloff *et al.*, 2013; Valenzuela *et al.*, 2014; Tedeschi *et al.*, 2021).

The fact that many introduced mammals represent a concomitant economic resource raises conflicts of interest where biodiversity conservation could be threatened. Indeed, introduced invasive mammals that are also game species are sometimes actually protected by laws and protected areas, such as establishing quotas and hunting periods with the aim of maintaining and improving populations (Sanguinetti *et al.*, 2014; Speziale *et al.*, 2014). In addition, game species sometimes represent a valuable socio-economic resource in rural areas (Jackson, 1988), where profit from the hunting industry (*e.g.*, hunting permits, tourist accommodation, local guides) represents an important business. These hunting businesses



and their incentives can conflict with conservation goals, such as when hunters seek to improve trophies by maintaining long-term populations, rather than controlling them in the short-term (Sanguinetti *et al.*, 2014). Unfortunately, in Argentina there are many problems associated with the hunting industry, including ineffective control and enforcement of laws, and limited benefits flowing to conservation.

## Hunting policy framework

An adequate legal framework is extremely important to solve environmental problems. In Argentina, there are several national-level laws that regulate the use and conservation of natural resources. However, the national constitution devolved the rights and responsibilities over natural resources to each province, where national-level policies are only valid if the provincial governments adhere to them.

The most important law related to wildlife conservation at the national level (National Law #22241) includes relevant aspects for introduced species management and control in Argentina. This law establishes the protection of wild fauna, without specific reference to their origin, taking into account individuals that live free and independent from humans, those that live in captivity or semi-captivity, and those that originally were domesticated and then became feral (Article #3). This law also regulates the importation, introduction or establishment of animals that can alter the ecological balance or affect economic activities (Article #5) and the release of captive animals without prior agreement of the corresponding authority (Article #6). These last two articles have vital importance in the species introduction processes in Argentina. Although it has not been documented conclusively, Article #6 has likely been violated on numerous occasions, contributing to the spread of introduced mammal species in much of the national territory. Specifically, regarding the impacts of introduced species, Resolution #376/97 (Ministerio de Ambiente y Desarrollo Sostenible) establishes that an environmental impact assessment is mandatory prior to the introduction of new species. The resolution even includes general guidelines for standardizing the procedure. Unfortunately, almost all game species introductions in Argentina occurred prior to this resolution in 1997.

Each year, the office that manages each province's natural resources determines the length of hunting seasons and the number of individuals that can be obtained for each authorized species (*e.g.*, Bulletin of La Pampa province and Article #16, Law #22421). In general, hunting is not allowed between June/July to March, which includes the reproductive period, without distinguishing whether species are native or introduced. In addition, the quota of hunted animals allowed varies among provinces and game reserves. On occasions, this type of regulation tends to protect and promote the development of populations (both native and introduced), and hence does not take into account the negative impacts that introduced species may have on native ecosystems. This is more relevant when hunting quotas are established for introduced species with high reproductive rates, such as the European hare (*Lepus europaeus*) or the wild boar (*Sus scrofa*). Indeed, the resolution for hunting in Argentina (National Decree #666/97), which regulates the conservation of wild fauna,

establishes the classification of species into four categories of hunting, including for sport, commercial activities, control (of harmful species), and scientific, educational or cultural reasons (Article #12). Again, this resolution does not emphasize the distinction between native and introduced species, including the section “Integrated Control of Harmful Species” (Articles #19 and #20). In this case, when the regulatory frameworks from the provincial and national levels are considered together, it becomes clear that there is an incoherent philosophical and theoretical approach to native and introduced species, which complicates the definition of effective management and control strategies for introduced invasive mammals.

Lastly, the Ministerio de Ambiente y Desarrollo Sostenible de la Nación coordinated the elaboration and implementation of the project “Strengthening of Governance for the Protection of Biodiversity through the Formulation and Implementation of the National Invasive Exotic Species Strategy” (GCP/ARG/023/GFF). This project was financed by Global Environmental Facility (GEF) and assisted by the United Nation's Food and Agriculture Organization (FAO). The strategy's main objective is to reduce the impact of introduced species on biodiversity, but also proposes the improvement of socioeconomic benefits, current and future conservation and sustainable use of biological diversity (*i.e.*, natural resources and ecosystem services) (SNEEI, 2017). The initiative is based on consensus with different public and private organizations to have an efficient prevention, early warning, control and monitoring system at country level, with coordinated and planned actions, as well as consistent and effective communication to prevent further introductions and expansions.

## Consequences of game introductions

Intentional releases, lack of control and poor fence structures of hunting reserves allow accidental animal escapes and subsequent establishment of feral populations. Indeed, all invasive ungulates have had escape events from the confinement from hunting ranches located in La Pampa, Entre Ríos, and Neuquén provinces (Petrides, 1975; Bonino, 1995; Novillo and Ojeda, 2008; Ballari *et al.*, 2016). The majority of invasive game species also have expanded their range from the introduction/escape locations in all directions. For example, the European hare expanded its range at a rate of 20 km/year in some areas, and now the distribution encompasses all continental Argentina (Bonino *et al.*, 2010; Monteverde *et al.*, 2019; see Valenzuela, this volume). Similarly, the wild boar is expanding its range at 3,500 ha per year in northwestern Patagonia and is now present in more than 30% of Argentina's territory (Pescador *et al.*, 2009; Ballari *et al.*, 2019).

The spread of invasive game species in Argentina causes numerous environmental consequences, which have been recorded to some extent (see Novillo and Ojeda, 2008; Ballari *et al.*, 2016). Both the European rabbit and hare are catalogued as pests in Argentina (Cuevas *et al.*, 2019; Monteverde *et al.*, 2019), and while there is little information on their ecological impacts in the country, these herbivores are suspected to have detrimental effects on vegetation, to compete for food and/or shelter with native mammals, and to disperse seeds of introduced plants (Jaksic, 1998; Bonino and Soriguer, 2009; Bobadilla *et al.*, 2020;

Bobadilla *et al.*, 2022). Indeed, Galende (2014) and Galende and Raffaele (2013) described partial diet and spatial overlap between rabbits and hares with the native rock specialist, the southern vizcacha (*Lagidium viscacia*). However, rabbits and hares also are “beneficial” to native predators by increasing the supply of prey and/or by decreasing predation pressure on native fauna (Jaksic, 1998; Novaro *et al.*, 2000). For example, up to 45% of mountain lion (*Puma concolor*) diet is comprised by European hare in Patagonia (Novaro *et al.*, 2000).

Many introduced ungulates are known to compete with native species, as they are selective browsers. Browsing usually alters plant community structure and composition by reducing regeneration, growth and survival of herb, shrub, and tree species (Côté *et al.*, 2004; Lees and Bell, 2008; Bonino *et al.*, 2010). For example, in Patagonia, red deer (*Cervus elaphus*) and fallow deer browse preferably on native plants, such as Chilean cedar (*Austrocedrus chilensis*), *Schinus patagonicus*, and maqui (*Aristotelia chilensis*), reducing plant cover and growth, while facilitating invasion of introduced trees (Veblen *et al.*, 1989; Relva and Veblen, 1998; Relva *et al.*, 2010; Barrios-García *et al.*, 2012; Relva and Sanguinetti, 2016). Moreover, diet overlap with the Patagonian huemul (*Hippocamelus bisulcus*) and Southern pudu (*Pudu puda*), which are native and threatened ungulates, has been suggested (Povilitis, 1981; Dolman and Wäber, 2008; Galende *et al.*, 2005).

Wild boar impacts native ecosystems by overturning extensive areas of vegetation to feed on roots, invertebrates and fungi (Barrios-García and Ballari, 2012). This disturbance is new to the native ecosystems of Argentina, as there are no native mammals with such foraging habits. Rooting by wild boar increases bare ground, reduces plant biomass, increase soil degradation, negatively affect perennial plant species, and facilitates further invasion by introduced plants (Barrios-García and Ballari, 2012; Barrios-García and Simberloff, 2013; Cuevas *et al.*, 2012; Nuñez *et al.*, 2013; Cuevas *et al.*, 2020; Cuevas *et al.*, 2021). Furthermore, wild boar depredates native monkey puzzle tree (*Araucaria araucana*) seeds and native rodent seed dispersers and could potentially threaten Araucaria forest regeneration and ecological processes, if boar numbers continue to increase (Sanguinetti and Kitzberger, 2010; Shepherd and Ditgen, 2012, 2013; Tella *et al.*, 2016). While the impact on animal communities (predation) in Argentina has yet to be assessed, it is known that wild boar host a number of diseases—including trichinellosis, brucellosis, and tuberculosis—that could harm both native mammals and livestock (Ruiz-Fons *et al.*, 2008; Meng *et al.*, 2009), and it could be a potential carrier of other diseases not yet registered in the country and devastating in economic aspects such as African swine fever (SENASA, 2018; see Uhart, this volume).

Some of the game species introduced in Argentina for hunting purposes were or are being controlled. Rabbits in Tierra del Fuego have been controlled by hunting, trapping, by introducing Pampa fox (*Lycalopex gymnocercus*) from mainland, and by using the myxoma virus in 1954 (Jaksic and Yañez, 1983). Nevertheless, there are still several focal areas, where populations are apparently growing (*e.g.*, the Ushuaia Peninsula and Parque Nacional Tierra del Fuego; Cuevas *et al.*, 2019; Bobadilla *et al.*, 2021). In Neuquén province, the myxoma virus is said to be used illegally since the 1980s, but rabbit populations are abundant and spreading southward (Galende, 2014). Hares, deer, and wild boar are all subject to hunting, although only during specific seasons and generally with a maximum daily limit (SAGyP,

2017). Additionally, the red deer has been successfully reduced through hunting in PNL (see Box 1, Sanguinetti *et al.*, 2014), and wild boar in PNEP (see Box 2, Ballari *et al.*, 2015a; Gürtler *et al.*, 2017). While all these efforts contribute to reducing introduced invasive species abundance and impacts, in general they are very limited in time and extent.

### **Sport hunting and protected areas**

During much of the middle of the 20th century, the problem of introduced species as a threat to biodiversity was not included in the political agenda for protected areas, and even less for those species with value for hunting. Introduced species were mostly considered as a natural resource to be exploited for social and economic benefits (see also Guichón *et al.*, this volume). For example, wild boar, red deer and European hare, widely distributed today, have been extensively exploited in Argentina because of their attractiveness as a species of big game and/or the quality of their meat and fur (Ballari *et al.*, 2019; Monteverde *et al.*, 2019; Relva *et al.*, 2019).

In particular, although red deer and wild boar are now present in many protected areas (Ballari *et al.*, 2019; Relva *et al.*, 2019; APN–SIB, 2020), sport hunting is only permitted in some sectors within Parque Nacional Lanín (PNL) and Parque Nacional Nahuel Huapi (PNNH) (APN, 2011). Both species were introduced in Patagonia between 1917 and 1922 for hunting purposes, before national parks were created, in a historical context influenced by the recent European immigration (Daciuk, 1978; Archibald *et al.*, 2020).

By the 1950s, red deer had expanded to the southwest of Neuquén province, and the Administración de Parques Nacionales (APN) authorities already had identified it as a threat to biodiversity within Parque Nacional Lanín (PNL) (created in 1937; Dimitri, 1959). In this historical context, sport hunting was allowed in this protected area in 1955, where hunters were allowed to access over 700 km<sup>2</sup> of public land by means of a payment by auction to the highest bidder. In this way, they still were able to acquire the right of 7–8 days access to hunting areas (2,000–6,000 ha in size) to kill trophies and females if they had interest. Later, in 1987, with the increase of distribution and abundance of red deer southwards, sport hunting was allowed in over 620 km<sup>2</sup> of public land in PNNH.

Since the 1990s, with the increase of economic interest in the region and the hunting of red deer, trophy sport hunting and female elimination was allowed in private lands within the areas designated “national reserve” in both national parks (Nahuel Huapi and Lanín). These areas are equivalent to Category VI areas with the IUCN classification system (IUCN and UNEP–WCMC, 2014). This authorization aims to exert hunting pressure on wild and self-maintained red deer population on private lands, prohibiting any management that promotes the increase of their distribution and abundance. However, hunting pressure, numbers and type of animal to be felled are all defined almost exclusively by ranchers.

At the same time, during recent decades, there has been growing concern about the impact on biodiversity, based on the accumulation of local scientific evidence (Veblen *et al.*, 1989; Relva and Veblen, 1989; Veblen *et al.*, 1992; Relva *et al.*, 2009; Flueck, 2010; Relva *et al.*, 2010; Barrios-García *et al.*, 2012; Nuñez *et al.*, 2013; Relva *et al.*, 2014; Relva and

Sanguinetti, 2016). Sport hunting in protected areas is still considered a valid strategy to reduce environmental impacts against biodiversity, if it is carried out within the context of red deer population management to maintain low densities (see Box 1; Sanguinetti *et al.*, 2014).

## BOX 1

### Red deer sport hunting and population management needs in protected areas

In Argentina, the occurrence of red deer (Fig. 1a) within protected areas is mainly restricted to those located in northern Patagonia, due to the history of introduction and spread associated with hunting interests in the early 20th century (Merino *et al.*, 2009; Relva *et al.*, 2019). During the last 60 years, red deer management in PNL and PNNH consisted mainly in allowing sport hunters to seek trophies, and optionally females, with the idea to exert hunting pressure without investing economic resources by the government. However, the government charges hunting licenses to, at least in theory, reinvest in population management practices. In addition to this sport hunting in both national parks, in recent years some red deer control hunting projects have been developed in these and other protected areas.

The main conflict between conservation and sport hunting within protected areas lies in determining the red deer population density that is compatible with maintaining sensitive biodiversity components. To face this conflict, the APN defined in 1986 the first policy and management guidelines for red deer to put trophy hunting in the context of population management (Ramilo *et al.*, 1986). This policy defined management actions and strategies to limit new introductions and avoid the dispersion to new areas. In areas already invaded, the policy promotes control actions to maintain populations stable at low density and sex ratio close to 1:1, assuming that this demography conditions enhance the development of high-quality trophies (Mysterud *et al.*, 2001; Kruuk *et al.*, 2002; Putman, 2004). In this context, the government considered that sport hunting is an acceptable tool to achieve biodiversity conservation goals and gives hunting opportunities to different kinds of hunters (Fig. 1b), as long as it is applied within the framework of population management for the species and therefore, must be combined with complementary hunting to remove females, offspring and young individuals.

Strategies to successfully reach the overall conservation objectives (*e.g.*, avoid dispersal, limit new introductions, etc.) can be applied using different management approaches and control methods, depending on the protected area, its conservation values, and the status of the red deer invasion. Concessions and management plans with social participation for control or commercial hunting were identified as valid approaches. Aerial or ground (diurnal and nocturnal, including dogs) hunting methods were considered depending on conservation goals, biodiversity at risk and red deer invasion scenario. This approach also provides economic opportunities to settlers and residents by allowing them to participate in red deer management, while abandoning or reducing historical land degradation of livestock grazing. In synthesis, the general idea was that government mainly offered hunting possibilities and economic opportunities to local communities, with little investment in red deer population management.

After 35 years since the policy was established, it has been poorly applied regionally. Only short-period red deer population management experiences were carried out between 2008–2012 in PNL (PNL, 2012; Sanguinetti *et al.*, 2014; Fig. 1a-c), a control plan on Victoria Island (PNNH, 2020) and the Ñirihuau area within PNNH, a control plan in Parque Nacional Lihué Calel since 2013 (Pastore *et al.*, 2013), and one in Parque Nacional Los Alerces since 2019. Additionally, in Parque Nacional Lago Puelo (where the red deer does not yet have stable populations), there is an action protocol to control progress when individuals are found (Pastore *et al.*, 2017).

During the last 30 years a great deal of scientific information about red deer ecology, management and their impact in Patagonia was published (Relva and Sanguinetti, 2016). Red deer management should be carried out based on population conditions (sex ratio, density ranges) and in relation to biodiversity conservation goals threatened by this invasive species. Furthermore, the management should consider sexual and spatial segregation, as well as the influence of habitat type within environmental gradients and climate variability on population dynamic. Therefore, different population management practices should be applied, with control methods and hunting pressure against each age and sex classes, varying in space and time at public and private lands within and outside protected areas (Flueck *et al.*, 1995; Nugent *et al.*, 2011; Relva and Sanguinetti, 2016).

The debate continues about how to conserve valuable ecosystems and endangered species in the context of red deer as a threat. This debate lacks an explicit and precise conceptual and regulatory framework that links the relation between red deer densities and population structure, with the loss of native conservation targets and trophy quality. For example, although there is a solid scientific background showing that the improvement of trophy quality implies the removal of females and young individuals (Tremblay *et al.*, 2004; Milner *et al.*, 2006), local hunters do not accept this management strategy. Without a more coherent framework, no measurable conservation and management goals can be defined for an explicit agreement between stakeholder's and the government. Only with an explicit and holistic approach, will it be possible to discuss which control methods are needed to effectively reduce deer densities, while improving trophy quality.



**Figure 1.** a. Red deer female; b. hunters walking through the temperate forest; c. technicians of Parque Nacional Lanín processing samples from deer hunting. (Photos: N. Pastore [a], N. Ferreira [b-c]).



## BOX 2

### Hunting control of wild boar in Parque Nacional El Palmar

Wild boar is one of the more widely distributed introduced mammals in Argentina, occurring in at least 46 protected areas (Ballari *et al.*, 2015a, Ballari *et al.*, 2019). This species causes soil disturbances, vegetation damage, diseases transmission, introduced seed dispersal, competition with native species, among other negative impacts (Barrios-García and Ballari, 2012; Cuevas *et al.*, 2012; Ballari *et al.*, 2015b). Additionally, through predation and habitat destruction, wild boar impact avian, reptile, amphibian, and small mammal populations (Ballari and Barrios-García, 2014). Lastly, wild boar affects economic human activities by damaging crops and transmitting diseases to livestock (Barrios-García and Ballari, 2012). Based on the wild boar's potential demographic growth and its wide range of negative impacts on biodiversity and ecosystem processes, there is an increasing need to design management strategies to minimize future environmental and socio-economic impacts (Sanguinetti and Pastore, 2016).

In Argentina, the wild boar is categorized as a high priority for management by Valenzuela *et al.* (2014); however, no national initiatives are available to control their populations (Ballari *et al.*, 2016). Nevertheless, management of wild boar has been applied in some protected areas, such as the PNEP, where control efforts have been carried out for more than 10 years (Gürtler *et al.*, 2017). This protected area was created in 1965 with the aim of conserving the last remnants of yatay



**Figure 2.** a. Information signs to prevent tourists and visitors from entering the area where the control of introduced animals with firearms is carried out; b. elevated construction, called *apostadero* or deer stand, used to hunt axis deer and wild boar; c. park rangers, volunteers and hunters, working together to record data. (Photos: S.A. Ballari).

palm (*Butia yatay*) groves. It has an area of 8,500 ha and is located in Entre Ríos province in the Espinal ecoregion. Due to known impacts of several introduced mammals inhabiting the park (e.g., wild boar on yatay palm seedlings; Pignataro, 2010), the PNEP administrators decided to carry out a control plan (Ballari *et al.*, 2015b) (Fig. 2). While introduced mammals have been sporadically hunted for control since 1983, the protected area managers began a formal and systematic Invasive Mammals Control Plan in 2006, including not only wild boar, but also axis deer and blackbuck, the latter with circumstantial presence (Gil, 2008). This program recruits local sport and subsistence hunters under a regulated framework that is controlled and directed by park rangers to contribute to the objectives of the protected area (Fig. 2a-c). In fact, this is the first management program in Argentina that allows authorized third parties to conduct controlled hunting on national park property, where there are no quotas nor trophy selection (Gürtler *et al.*, 2017).

Different hunting methods (e.g., hunting with horse and dogs, hunting from a truck) have been used for wild boar with different success, but the method most used and most effective over time was hunting with firearm from a high elevated structure. These hunting fixed high points, called *apostaderos* in Spanish or deer stands in English (Fig. 2b), are located in areas with good visibility throughout the entire protected area and encompassing different habitats. Hunters use soaked corn as bait to attract the animals, which is replenished on a daily basis (Ballari *et al.*, 2015b).

The management plan in the PNEP has substantially reduced wild boar abundance during the first two years of the program, and then kept low abundances the following eight years. Furthermore, soil rooting area in the park declined (Gürtler *et al.*, 2017), and predation of yatay palm seedlings dropped to almost zero (Lunazzi, 2009; Ballari, 2014). The success of the plan may also be attributed to the joint involvement of park personnel and local recreational hunters (Fig. 2c), continued institutional support, and increased awareness of wild boar impacts, among others (Gürtler *et al.*, 2017). However, while this plan has proven to be successful for wild boar, when hunting efforts are reduced or stopped for a few months, wild boar population recovers rapidly (Ballari, S.A.; personal observation). This demonstrates that systematic control sustained over time, as well as regular monitoring, are critical for the success of the plan.

This long-term (and currently active) program is unique in Argentina because it has been effective in reducing wild boar populations, decreasing poaching, expanding the number of local stakeholders interested in the control program, and strengthening relationships between protected areas and the local communities (Gürtler *et al.*, 2017).

## Changes in sport hunting within protected areas: opportunities and limitations

The sport hunting scheme implemented on public lands within protected areas needs to generate, in addition to the hunting opportunity, incentives for the people involved (*i.e.*, hunters, guides, managers, etc.). To improve trophies in the long-term it is necessary to promote the annual removal of animals of all age classes and both sexes (Flueck *et al.*, 1995). Furthermore, it is necessary to invest economic resources, improve the organizational governance capacity, and create effective educational programs for key stakeholders (Nugent *et al.*, 2011; Relva and Sanguinetti, 2016). This approach will facilitate agreements to promote management schemes and population monitoring to improve trophy quality as a product of management (Flueck *et al.*, 1995; Relva and Sanguinetti, 2016) that prioritizes native ecosystem conservation.

To implement effective management schemes inside and outside protected areas, it is essential to integrate the work between scientists and managers to achieve solid agreements to improve legislation and management related to protected areas and introduced species (Sanguinetti *et al.*, 2014). The current economic and organizational capacities in protected areas limit the achievement of a comprehensive and efficient management of introduced invasive mammals. Finally, it is also necessary to achieve a cooperative approach to pursue the multiple objectives (*e.g.*, create economic incentives, decrease animal populations) that are demanded by the different social actors (Flueck *et al.*, 1995; Nugent *et al.*, 2011; Sanguinetti, *et al.*, 2014; Relva and Sanguinetti, 2016).

## Concluding remarks

Hunting represents a highly profitable activity worldwide. Indeed, hunting is the main driver of mammal introductions in Argentina, where new hunting reserves are being authorized and established every year. While most introduced mammals are confined in enclosed areas, it is well known that fences and regulations tend to be deficient and also, deliberate releases may occur. This fact raises the urgent need to improve policies and institutional frameworks related to introduced species hunting. Furthermore, it denotes that we still suffer gaps between social and ecological values, and conservation priorities and subsequent actions. This analysis reinforces the need to develop integrated research, regulations, and legislation that considers both the cultural and economic use of introduced species, as well as the ecological costs when they become invasive (Ballari *et al.*, 2016; Archibald *et al.*, 2020).

Many species introduced for hunting purposes cause direct and indirect negative impacts on native biodiversity and ecosystem processes. This issue is especially relevant when introduced species occur in protected areas. While there are successful management experiences (wild boar in PNEP, and red deer in PNL), we highlight the importance of reinforcing hunting regulations, and the development of fauna management protocols to successfully face new sources of escape, while achieving conservation objectives. Also, it is important to evaluate sport hunting management success, by monitoring population trends and environmental impacts, instead of only considering the quality and number of trophies. Lastly, management strategies, according to recent studies, need to be developed regionally with a socio-ecological vision and multi-sectorial participation of decision-makers, protected area managers and private landowners (Ballari *et al.*, 2016; Cuevas *et al.*, 2016, Sanguinetti and Pastore, 2016).

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# INTRODUCED INVASIVE MAMMALS OF ARGENTINA

Introduced Invasive Mammals (IIMs) are a major driver of global and local environmental change, including negative impacts on biodiversity, ecosystem processes, economies, health and other social values. However, as complex social-ecological systems, invasive species cannot be conceived solely as “negative,” nor merely as “biological” invasions. This book presents conceptual and practical perspectives from 49 authors with expertise in communication, ecology, education, genetics, history, philosophy, social sciences and veterinary medicine to better understand and manage IIMs in Argentina. It concludes by providing updated information on Argentina's IIM assemblage, which includes 23 species.

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and Ricardo A. Ojeda, EDITORS**



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