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INVASION NOTE

Invasive wild boar in Argentina: using protected areas as a research platform to determine distribution, impacts and management

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Abstract The wild boar is an invasive ecosystem engineer in Argentina that has lacked sufficient basic information to determine applied actions. The current distribution, impacts and management of this species were analyzed using the expert opinion surveys of protected area managers. The boar is widely distributed and occupies most of Argentina's terrestrial ecoregions. Moreover, its populations are common, and its abundance is growing in most of the protected areas. Boars were recorded mostly in wetlands, forest and shrublands. Managers also reported a wide range of negative impacts, which included soil disturbance, vegetation damage and animal predation. Several control method types are used and in most protected areas, more than one are applied, but hunting was the most used technique. However, the effectiveness of control methods was low, suggesting the need of an urgent plan to define coordinated management actions to minimize the negative impacts of this species and also to prevent its expansion into new areas.

Keywords Conservation · Control methods · Ecosystem engineer · Feral pig · *Sus scrofa*

Introduction

The wild boar (*Sus scrofa*), native to Eurasia and North Africa, is one of the most widely distributed invasive

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exotic species in the world, being found in all continents except Antarctica (Long 2003). The success of this species in colonizing a wide variety of habitats is partly due to its biological characteristics, such as high reproductive potential, adaptability to live in different habitats, omnivorous diet, broad native range, wide tolerance to different climatic conditions and behavioral plasticity to human presence (Coblentz and Baber 1987; Podgórski et al. 2013; Ballari and Barrios-Garcia 2014). As an invasive exotic species, the wild boar not only causes serious damage to plant and animal communities, but also modifies ecosystem processes via physical alteration of the environment (Barrios-García and Ballari 2012). In this way, it also constitutes an invasive ecosystem engineer (Crooks 2002). The negative impacts on biodiversity and on the environment occur in native and introduced ranges, and includes predation of seedlings and seeds, dispersion of exotic plant, disturbance of soil properties, resource competition with native species; predation on vertebrates and invertebrates, crop damage, and disease transmission (Barrios-García and Ballari 2012). Particularly in Europe during the last decades, wild boar population growth in terms of abundance and distribution and has caused economic losses mainly related to crop damage (Schley et al. 2008; Massei et al. 2011). Also in North America, it has been reported that the boar is increasing its populations and expanding its distribution, not only affecting native biodiversity but also causing economic losses (Pimentel 2002; Pimentel et al. 2005). Due to the variety and magnitude of its impacts, a wide range of control and management strategies have been developed and implemented around the world. These, individually or collectively, show variable effectiveness, which depends on intrinsic and extrinsic factors, including the size of the area, population size, funding, policy making and public acceptance (Massei et al. 2011; Bengsen et al. 2014). In South America, particularly in Chile and Argentina, the wild boar is considered to be among the most harmful of invasive ungulates (Jaksic et al. 2002; Novillo and Ojeda 2008).

The wild boar was introduced from Europe to Argentina in 1906 for sport hunting, and subsequently around 1914, many boars escaped from captivity and spread throughout much of Argentine territory (Navas 1987). Various studies have addressed the wild boar's diet, habitat use and impacts in Argentina (Cuevas et al. 2012, 2013a, b; Merino and Carpinetti 2003; Pérez Carusi et al. 2009; Pescador et al. 2009; Sanguinetti and Kitzberger 2010; Schiaffini and Vila 2012), but most are geographically limited to the Patagonian forest and Monte Desert ecoregions. However current information about country-level remains scarce or unavailable. In this context, protected areas (PAs) provide a research platform to study distribution, impacts and management variables of exotic invasive species. Moreover, PAs are fundamental to achieve global conservation strategies, but their effectiveness can be reduced by external pressures (Leroux and Kerr 2012), such as biological invasions. The Argentine *Sistema Federal de Areas Protegidas* (*SIFAP*–Federal System of Protected Areas) consists of 402 PAs, representing 9.6 % of the country's total surface area and including all major national ecoregions (SIFAP 2012). Due to increasing wild boar abundance and damage, PA administrators face challenges to manage this exotic species. Furthermore, it is not realistic to wait for complete information to make decisions to conserve native biodiversity, mainly for management of elusive exotic species for which little is known (Donlan et al. 2010). As such, expert opinion is increasingly used in the conservation sector and is particularly useful in data-poor scenarios (Donlan et al. 2010). PA managers' expert opinion surveys constitute a way to assess the current information about wild boar in southern South America and serve as a baseline for this species. Furthermore, this approach is relatively inexpensive and quick to conduct, and it provides information about wild boar for planning, prioritization and implementation of management strategies (Campbell and Long 2009), specially in PAs where this invasive species was identified as a serious conservation problem (Merino et al. 2009). This study sought to provide an updated overview of the wild boar's distribution, population trends, impacts and management in Argentina, based on expert opinion surveys of PA managers.

Methods

We conducted during 2012–2013 an internet-based survey distributed to the responsible person for conservation and management policies at each PA. Contact and background information from each

protected area was obtained from online, public access databases: SIFAP (2012) and from the *Sistema de Información de Biodiversidad* (Biodiversity Information System; www.sib.gov.ar). We sent the online survey to all PAs for which we had contact information with the effort of obtaining information from representative PAs throughout Argentina with different protection categories. Additionally, an exhaustive literature review was performed to complement the information of these databases. The survey (either from empirical data or manager perception) included several questions about presence/absence of the species, year of the first sighting, relative population density (abundant, common, rare), population trends (increasing, decreasing, staying the same), habitats frequented, impacts (negative and positive; and different types), management/control strategies used currently and their effectiveness, and the existence of illegal hunt.

Effectiveness of management strategies was evaluated with generalized linear models (GLMs) using wild boar abundance in each PA as response variable, and presence/absence of each different control method, ecoregion, PA size and year of first sighting as explanatory variables. The Poisson regression distribution family with *log* link function and Akaike Information Criterion (AIC) for small samples (for model selection) were used.

Results and discussion

We obtained responses from 86 PAs, which comprise 21.6 % of national system and cover all 16 existing ecoregions (Fig. 1). Although the wild boar is present in Argentina for over 100 years, our results showed that the presence of this species in the PAs is becoming more evident since 1970s (Online Resource). Currently wild boars occur in most of Argentine territory, being reported in 26 of the surveyed PAs, distributed from 72°W, on the Andes Mountains, to 57°W, on the Atlantic coast, and from 24°S to 43°S (Fig. 1). Additionally, the only model that best explained wild boar presence and abundance was the null model which does not include any explanatory variable. Therefore, boar presence and abundance was not affected by the PA size, ecoregion, year of first sighting and control methods applied. Argentina has 16 different terrestrial biomes, and we found that boar are using 10 of them (62.5 %). Patagonian Forests, Pampa and Patagonian Steppe represent 54.5 % of the total records (Fig. 1), indicating that they occupy similar ecoregions to their native range. However, we also found that the boar is expanding into new habitats like Monte of hills and valleys, as described by Cuevas et al. 2010. These results could explain why boar abundance was not predicted by ecoregion. Indeed, this is the first work that describes the presence of wild boar for the Parana Flooded Savanna, Iberá Marshes, High Andean, Espinal, and Arid Chaco ecoregions. Additionally, the habitats most used by the species were wetlands (24.7 %), forests (23.5 %) and shrublands (23.5 %). These results are congruent with other studies, especially with those from its native range that describe preferences for environments with high water availability and high vegetation cover (Meriggi and Sacchi 2001; Fonseca 2008). Furthermore, previous studies have shown that high temperature could limit wild boar activity, especially in arid lands, because the boars lack of sweat glands or other cooling physiological mechanisms for maintaining the hydric and thermal balance (Rosell et al. 2001; Dexter 2003). However, this study recorded the species' presence in dry temperate environments, such as the Arid Chaco and Monte Desert which support the idea that boar have remarkable resistance and adaptation mechanisms to drought conditions, which was noted by Cuevas et al. (2013a, b).

Regarding wild boar population abundance, most PA managers indicated that the species was common (50 %), followed by abundant (34.6 %) and rare (15.4 %). The PA managers also denoted that this ungulates population was increasing in most PAs (65.4 %). These results suggest that boar populations are growing and invading new areas and other environments that are unlike those of its native range (e.g., High Andean and Arid Chaco). Globally, it has been demonstrated that boar' populations are growing significantly during last decades (Schley and Roper 2003), generating an expansion of its range and invading new environments. This phenomenon could be due to several factors, including climate change, development of agriculture and animal husbandry, among others (Waithman et al. 1999; Geisser and Reyer 2005; Saito et al. 2012; Podgórsky et al. 2013). Furthermore, in some remote areas of Argentina, wild boar is scarcely reported, but when sought is detected. For example, in the Fuegian Archipelago this species

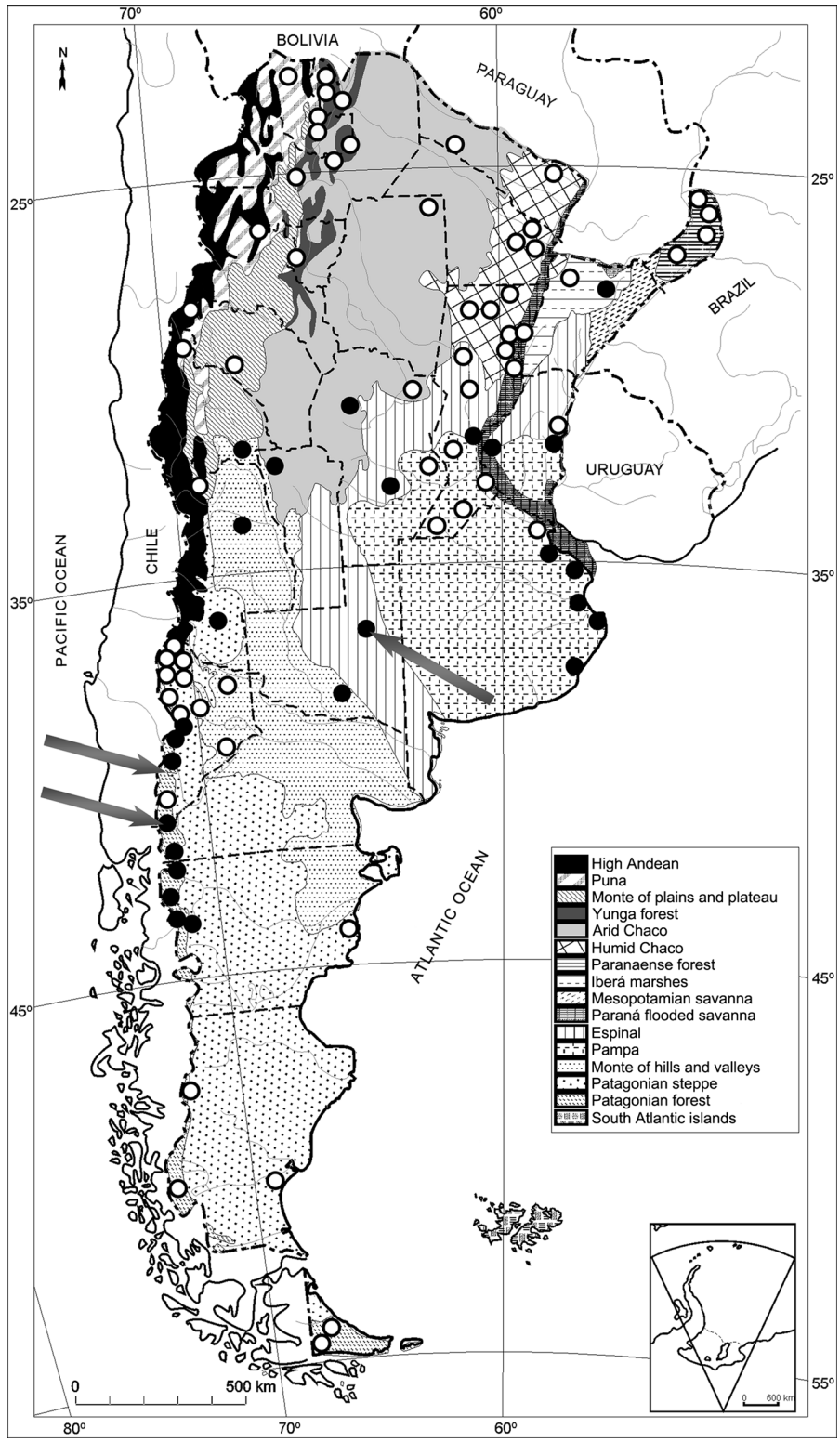

Fig. 1 Argentine terrestrial ecoregions and surveyed protected areas (PAs) that indicated presence (*black circle*) and absence of wild boar (*white circle*). The *grey arrows* show the known introduction sites of the species

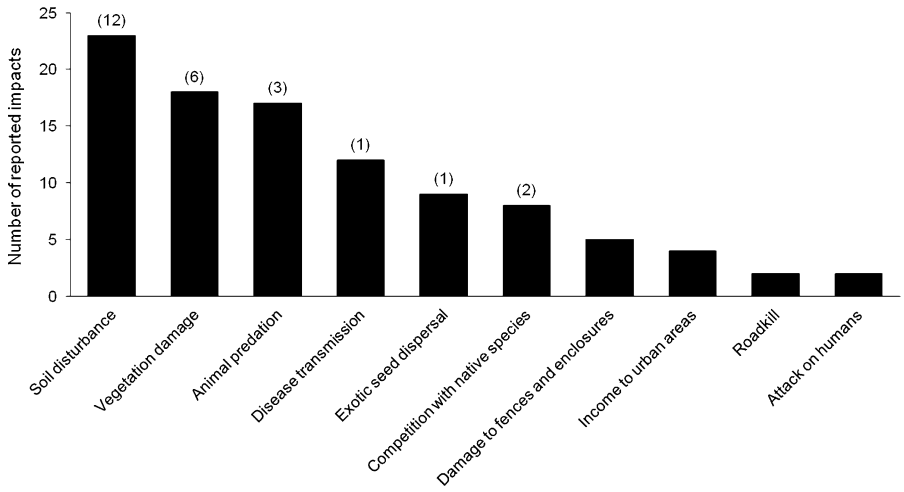

Fig. 2 Impacts made by the exotic wild boar (percentage) in Argentine protected areas. (*x*) indicates the number of areas where the impact was reported to be the greatest

was only recently confirmed in the literature despite being present for decades (Valenzuela et al. 2014).

According to PA managers' expert opinion, the wild boar generates several negative impacts on native ecosystems, human welfare and economic activities (Fig. 2), many of which directly or indirectly alter the availability of resources to other species by maintaining, creating or modifying the habitats where they live supporting their status as ecosystem engineer (Jones et al. 1994). By rooting (reported by 88.5 % of PAs were the species is present), the wild boar overturns extensive areas of soil, generating bare ground that modifies soil properties, facilitating the establishment of exotic plants, affecting the plant community composition, altering bacterial communities and causing erosion (Arrington et al. 1999; Wirthner et al. 2011; Barrios-Garcia and Simberloff 2013). Additionally, soil disturbance was reported for 12 PAs as the main impact of wild boar. Because rooting is one of the most visible and characteristic effects of wild boar, the perception of their frequency and intensity over other negative impacts (e.g., predation, competition) could be overestimated by PA managers. However, due to their opportunistic, omnivorous foraging behavior, PA managers also widely reported serious impacts to animal (wildlife, ground-nesting birds, and livestock) and plant communities (69.2 % for each category) via predation or damage. Particularly, soil property alterations and the impacts on plant and animal communities could endanger the conservation goals of PAs. There are only a few studies though that has focused on wild boar impacts on vegetation and soil properties in Argentina, whose they have shown that wild boar. Rooting activities facilitates the establishment of non-native seedlings, reduce plant cover, decrease plant richness and diversity, increase soil degradation and alter C/N ratio and predate on seeds of native tree species (Sanguinetti and Kitzberger 2010; Cuevas et al. 2012; Barrios-García and Simberloff 2013). However, no studies addressing wild boar impacts on native animal communities were developed.

Predation and environmental conditions are the main natural factors that could regulate wild boar populations, while hunting by humans is the main cause of unnatural mortality (Nores et al. 2008). However, in Argentina the wild boar does not coexist with any of their natural predators, and the only two native predators that could fulfill the role are the puma (*Puma concolor*), and the critically endangered jaguar (*Panthera onca*). However, the poor conservation status of these felid species, mainly due hunting and habitat fragmentation, could lead to dramatic decrease this potential predator–prey interaction (Paviolo et al. 2008). Regarding management, only 53.8 % of the surveyed PAs surveyed performed some type of control strategy. Among them, 78.6 % used more than one method (Online Resource). PA managers' reported that hunting was the most used technique (71.4 %) and particularly very effective when conducted with horses and dogs. Additionally, 28.6 % of the PA managers reported the use of traps as control method. However, our results showed that the currently applied methods and their combinations, used to

control wild boar populations in PAs (explanatory variables of the GLM), are ineffective and do not reduce the abundance of this exotic species, especially considering that the population is undergoing an expansion into new areas. Furthermore, 69.2 % of the surveyed PAs had illegal hunting of wild boar. In Argentina this species is offered as a big game trophy in many provinces, giving it economic and cultural value (e.g., La Pampa, Cordoba, Neuquén, Rio Negro, and Buenos Aires Provinces). However, hunting activities and game reserves are mainly planned to sustain and improve the resource and not for the control or eradication of the species. While Merino et al. (2009) indicated that sport hunting does result in some control of wild boar' populations, Pescador et al. (2009) uncovered no significant impact of this activity on the ungulate's abundance, which is consistent with our results.

It has been demonstrated that the key aspects to achieve effective wild boar management are (i) to carefully plan the tasks, (ii) to combine different control techniques, and (iii) to maintain a long-term program to ensure the monitoring of populations (Massei et al. 2011). Numerous management programs have been developed to minimize this species' impacts or eliminate its populations, either in its native or exotic ranges. However, several of these programs have not been planned or funded properly and often lack clearly defined or realistic objectives (Campbell and Long 2009). Despite the fact that in some regions of Argentina the wild boar was categorized as a high priority for management (e.g., Valenzuela et al. 2014), there are neither a control/eradication program nor an agreement about more appropriate methods for its management between national, provincial or protected area levels. Nevertheless, we believe that it is feasible to implement specific management programs that use control methods that have proven successful and low cost, such as hunting with dogs, hunting from blinds bait and hunting whit vehicles (Campbell and Long 2009). Eradication in continental areas, however, is difficult but it has been achieved, largely on small islands (Massei et al. 2011; Veitch and Clout 2002). Yet, because the boar can quickly recolonize areas where it has been removed, it is also highly expensive and logistically complex to maintain wild boar-free areas. So that, management at the national level should aim to reduce the boar population, minimizing the negative impacts, applying control methods that can be maintained over the time and monitored regularly to obtain better results. We recommend the development of a national strategy for the management and control of wild boar populations in sensitive conservation areas, in the edges of its distribution reducing the probability of range expansion, and in agricultural crops as well, where the boar can seriously affect production and cause economic losses (Pimentel et al. 2001). This national strategy should contemplate a long-term assessment to monitor impacts before and after applying the management techniques in order to achieve greater effectiveness (Campell and Long 2009). Furthermore, for greater success Bieber and Ruf (2005) suggested that it should be necessary to include data from environmental productivity such as fruit production, wet season or resource pulses. They found more effect on reducing boar population growth when under good environmental conditions they hunted juveniles and a strong hunting pressure on adult females during years with poor conditions. Finally, we believe that these management plans must be products of a collaborative work among decision makers, PA managers and the scientific community, and must also have the key support of the public, because these programs are always under increased pressure from scrutiny of public spending and animal welfare (Bengsen et al. 2014; Estevez et al. 2014).

The wild boar in Argentina is expanding its range, as in other places around the world (Toïgo et al. 2008). This study is consistent with a world-wide review on the damage caused by this species in either its native and exotic ranges (Barrios García and Ballari 2012). However, more studies focused on understanding the ecology of exotic wild boar impacts and control methods are necessary, especially in PAs. In Argentina, the scarcity of predators, added to the ineffective control methods applied, the diverse of negative impacts registered, the growth of their populations and the extraordinary resilience of this species, suggests that it could be very meaningful for conservation scientists and managers to dedicate effort to improving the efficiency and effectiveness of wild boar control methods. For this reason, it is essential to delineate management strategies to mitigate the potential damage that this species may have on places where it is already established and primarily to prevent the invasion of new areas.

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