Rapid Communication

First records of non-native Eurasian wild boar *Sus scrofa* (Linnaeus, 1758) (Mammalia: Artiodactyla) in a coastal ecosystem of Temperate Forest of south-central Chile

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Abstract

We report the first casual record of Eurasian wild boar *Sus scrofa* in Nahuelbuta Mountain Area, located in the coastal Temperate Forest of south-central Chile. Camera-trapping was conducted between January 2018 and February 2019 at two sites comprised by native native forest and commercial tree plantations. Wild boars were detected within plantations of Monterey pine mainly during Austral summer (December to February), daytime (between 11:00 and 20:00) and close (3 km) to Nahuelbuta National Park. The combination of its highly adaptable generalist behaviour and the extensive presence of commercial tree plantations in Nahuelbuta Mountain Area may favour the expansion of the invasive wild boar throughout this imperilled ecosystem, including its potential occurrence within the small and isolated protected areas present in it.

Key words: camera-trapping, invasive species, Nahuelbuta Mountain Area, exotic tree plantations

Introduction

Invasive species have contributed to the loss of biodiversity and ecosystem degradation at global scales (Sala et al. 2000; Pysek and Richardson 2010), warning to conservation managers to deal with their early invasion stages. According to the Species Survival Commission of the International Union for Conservation Nature (IUCN), the Eurasian wild boar (*Sus scrofa*) is among the most ecologically destructive invasive species in the world (Lowe et al. 2000). The success of wild boars as invaders has been associated to intrinsic properties of the species, such as its ability to adapt to a variety of habitat types, omnivorous foraging behavior, and high reproductive rates. On the other hand, several extrinsic causes have promoted wild boar spread, including illegal transportation and release, frequent escapes from farms, the propensity to thrive in human-altered landscapes, and a lack of native predators (Seward et al. 2004; Mayer and Brisbin 2008; Bevins et al. 2014).

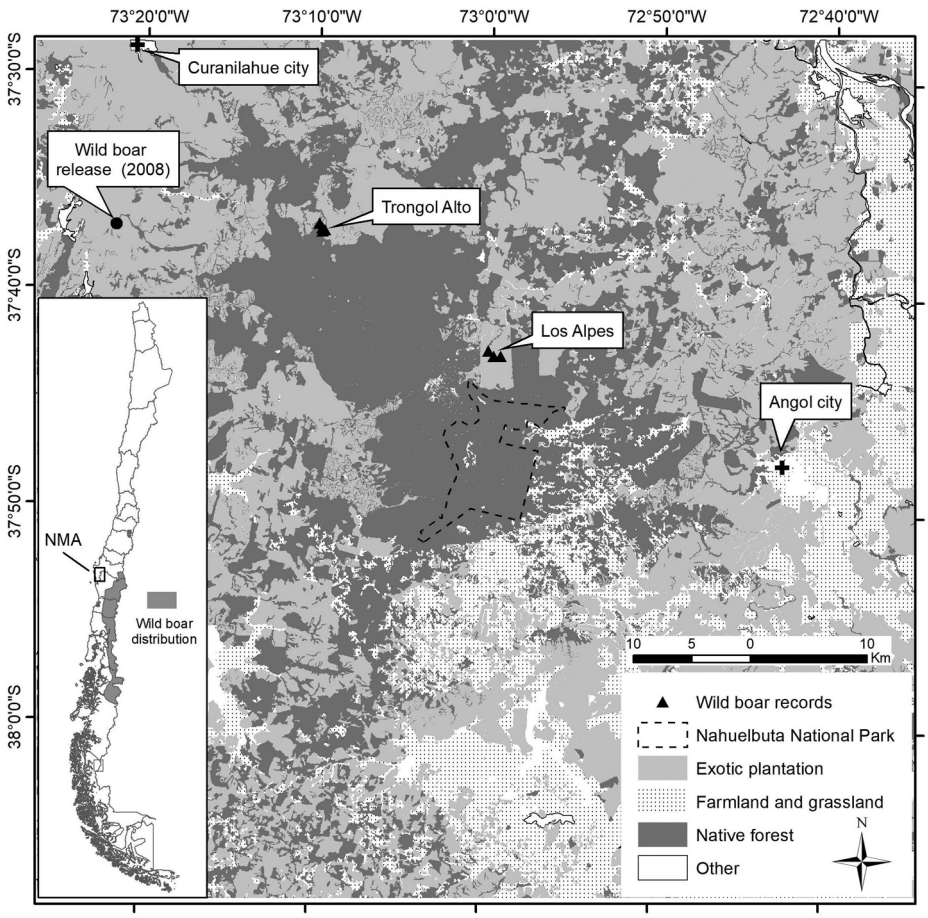

Figure 1. Eurasian wild boar (*Sus scrofa*) records (black triangles) in Los Alpes and Trongol Alto sites in the Nahuelbuta Mountain Area (NMA) of south-central Chile, during 2018–2019 camera-trap monitoring. Grey areas on the left inset represents the known distribution range of the species in Chile based on Skewes and Jaksic (2015).

Wherever the wild boar has been introduced, it has dramatically altered the function and health of native ecosystems. Some of these impacts include the modification of plant communities through herbivory, predation on native terrestrial arthropods and vertebrates, high levels of soil erosion and spread of pathogens that affect animal and public health (Barrios-García and Ballari 2012; Ballari and Barrios-García 2014).

In Chile, wild boars were introduced in the middle of the 20th century at different locations across Andean temperate forest and Patagonia (Jaksic 1998; Jaksic et al. 2002). Whereas early introductions were conducted for hunting purposes, natural wild boar movement across the Andes and escape and release of animals from farms in south-central Chile have promoted wild boar expansion along the country in the recent decades (Skewes and Jaksic 2015). Currently, wild boars are reported to distribute from O'Higgins region (northern limit) to Aysén region (southern limit), occupying areas through the Andean slopes of temperate forest, central valley depression, and the coastal range of temperate forest (Figure 1). At southern coastal areas, wild boars have been reported in Los Ríos region to the present date, likely resulting from accidental escapes from clandestine farms (Skewes and Jaksic 2015).

Wild boars cause significant alterations to the ecosystems and public health. The species impacts both local wildlife and plant communities by preying on native species of insects, mammals, birds and amphibians (Skewes et al. 2007), and altering the density, coverage and diversity of several understory plant species (Álvarez 2017). Moreover, wild boars are reservoirs of pathogens of high concern for cattle and human health (García et al. 2005; Gortázar et al. 2007), and thus, further evidence about the presence of this harmful invader is warranted to inform management and control measures across its geographic range in the country.

Here, we documented the presence of wild boars in Nahuelbuta Mountain Area (hereafter NMA), a vanishing ecosystem of high biological value located in the coastal temperate forest in south-central Chile (Smith-Ramírez 2004). The species has exhibited a progressive expansion across Andean slopes (Figure 1), and confirmed records in coastal zones near to NMA have been almost absent so far (Skewes and Jaksic 2015).

Materials and methods

The Nahuelbuta Mountain Area (hereafter NMA) ranges across 150 km from Biobío to Imperial rivers in south-central Chile (35°–40° S) (Figure 1). The landscape of NMA consists of a mosaic of native forest and human-created lands, including evergreen and deciduous tree species of *Nothofagus* species, and large stands of exotic plantations of Monterey pine (*Pinus radiata*) and different species of eucalyptus (*Eucalyptus* spp.), as well as open agricultural lands (Otavo and Echeverría 2017). Between January 2018 and February 2019, we conducted all-year-round camera-trapping primarily focused on detecting native mesocarnivores. Cameras were installed at two sites (central points): Los Alpes (LA; 37°43.4′S; 72°59.5′W) and Trongol Alto (TA; 37°37.2′S; 73°8.8′W). Both sites are Mininco forestry company lands – located *ca*. 20 km apart each – and they are part of a network of Priority Biodiversity Areas across the NMA (Figure 1).

Los Alpes (ca. 17.5 km^2) includes mixed vegetation of deciduous forest dominated by roble (*Nothofagus obliqua*) in ravines, and large stands of plantations of Monterey pine. Trongol Alto (ca. 60 km^2) is mainly comprised by deciduous forest dominated by roble and coigüe (*Nothofagus dombeyi*) to the west portion, and plantations of Monterey pine restricted to the east portion (Figure 1). Los Alpes and TA are located 24 and 20 km from Angol and Curanilahue, respectively, which are the closest cities around the study area, and LA is 3 km from the border of the Nahuelbuta National Park, the largest protected area in NMA (68 km^2; Figure 1).

Monitoring involved three grids of nine camera stations each (one grid at LA and two grids at TA), which were deployed at a minimum 1 km-distance between cameras (Figure 1). Cameras (Bushnell Trophy Cam, Bushnell Corporation, Overland Park, KS, USA) were mounted on trees *ca*. 50–60 cm

above the ground and baited with a commercial lure (Fox Urine, Predator Pee, Maine, USA). For descriptive analyses purposes, we considered as independent events wild boar photos recorded at different sites or separated by at least 24 hours at the same site (Moreira-Arce et al. 2015a). Photos of wild boars confidently identified as distinct individuals based on unequivocal physical differences were considered as independent records as well. For this we used differences of body size and coat color patterns (Massei et al. 2018). Despite the number of independent pictures of a species at a camera has been associated to abundance (e.g. Palmer et al. 2018), this index is mostly related to detection probability (Burton et al. 2015). Thus, we used the number of pictures simply to inform behavioral observations.

Results

We accumulated a sampling effort of 8,343 camera-days at both surveyed areas (LA: 3,220 camera-days; TA: 5,123 camera-days) and obtained a total of 32 independent wild boar photos, with eight photos recorded at LA and 24 photos recorded at TA (Table S1). All records were captured at camera stations dominated by Monterey pine plantations (Figure 1), and corresponded to single wild boars, except for two animals that were recorded roaming together at LA (Figure 2). Wild boar presence was mostly concentrated in the Austral summer between December and February (28 out of 32 photos; 88%), and the species was more active during daytime, with most records distributed at 13:00–14:00 and 17:00–19:00 (Figure S1).

Discussion

Our records likely relate to a relatively recent and local wild boar presence (since about 10 years ago), which may be expanding in the coastal range of the Biobío and Araucanía Districts. Two lines of evidence support this hypothesis. First, the apparent absence of sightings of either wild boars or their indirect signs reported by forestry workers, local communities and other research teams in native forest and exotic plantations in the study area. Secondly, an exceptional event occurred in 2008, when wild boars were seen roaming freely in mountain terrains between the cities of Los Álamos and Cañete, likely related to animal escapes that occurred from a farm located at this sector (Skewes and Jaksic 2015). Although releases were considered as unsuccessful (i.e., last male wild boars were likely hunted down by 2012), it is not possible to rule out natural movement of wild boars from the original release area, which is located to about 17 km from the closest camera point where a wild boar was detected at TA (Figure 1). Alternatively, deliberate and/or accidental wild boar introductions may have occurred through adjacent sites, driven by either escapes from clandestine

Figure 2. Individuals of Eurasian wild boar (*Sus scrofa*) detected at camera-trap locations in Los Alpes site, Nahuelbuta Mountain Area, south-central Chile (January 2018–February 2019).

farms or human-aided movement from other unknown locations for hunting purposes, as seen in other locations worldwide (e.g., Bratton 1975; Waithman et al. 1999; Zivin et al. 2000). For instance, the relatively recent expansion of wild boars from Andean locations to the intermediate depression may be enhancing the species colonization through the Coastal mountain range of south-central Chile (Skewes and Jaksic 2015).

The NMA represents a zone of biodiversity transition between northern mediterranean-sclerophyllous and southern temperate species (Villagrán

and Armesto 2005). Consequently, this ecosystem comprises numerous endemic species of flora and fauna that found refuge during the last glaciation (Villagrán 1990; Smith-Ramírez et al. 2019). Despite the ecological significance of NMA, the ecosystem has been largely exposed to the transformation of native habitat by agricultural lands, and more recently by commercial tree plantations (Aguayo et al. 2009; Echeverría et al. 2006). Accordingly, most of the endemic flora and fauna of NMA, including species of amphibians (Castro-Carrasco and Ortiz 2019), lizards (Troncoso-Palacios 2019), mammals (Moreira-Arce et al. 2015b), terrestrial arthropods (Barahona-Segovia 2019), woody and non woody plants (González et al. 2006; Atala et al. 2015), present a high risk of extinction. Yet, this outstanding biodiversity is safeguarded within two small and isolated protected areas present in NMA (Nahuelbuta National Park and Contulmo Natural Area) surrounded by agricultural and forestry lands. Potential expansion of wild boars in the NMA may be favoured by extensive commercial forestry plantations and agriculture lands, which are preferred by this highly adaptable generalist species as source of food and thermal refuge (Lantschner et al. 2013; Ballari and Barrios-García 2014). Moreover, wild boars may favour the dispersion of non-native ectomycorrhizal fungi, which in turn can promote exotic pine trees invasion (Nuñez et al. 2013). Thus, the progressive colonization by the invasive wild boar throughout NMA, and particularly its occurrence within the two protected areas, may severely alter the integrity and health of this imperilled ecosystem, warranting further systematic studies about the population estimation and distribution of the species through the region. Unfortunately, the camera-trapping design used in this study, and the small number of independent events along with the difficulty of distinguishing different individuals in most of the pictures prevented us to estimate a reliable number of animals roaming the surveyed areas (e.g. Peris et al. 2019). Short term actions including an extensive camera-trap survey are needed to elucidate to what extent the species is presented in NMA. Future population genetic analyses could also be used to infer patterns of connectivity and dispersal among sampling locations and other adjacent sites, improving our understanding about the location-specific ecology of wild boars. Findings would be pivotal to inform both legislative and regulatory management focused on this invasive mammal in the NMA and other regions in Chile.

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References

Aguayo M, Pauchard A, Azócar G, Parra O (2009) Cambio del uso del suelo en el centro sur de Chile a fines del siglo XX: Entendiendo la dinámica espacial y temporal del paisaje. *Revista chilena de historia natural* 82: 361–374, https://doi.org/10.4067/S0716-078X2009000300004

Álvarez F (2017) Caracterización y cuantificación del efecto de las hozaduras de Jabalí (*Sus scrofa* Linnaeus, 1758) en el sotobosque de un bosque de Araucaria-Lenga en la Reserva Nasampulli, región de la Araucanía, Chile. Natural Resources Management Thesis, Universidad Austral de Chile, Valdivia, Chile, 48 pp

Atala C, Pereira G, Romero C, Muñoz-Tapia L, Vargas R, Suz LM (2015) Orchidiod fungi of the form-genus *Rhizoctonia* associated with the roots of *Chloraea cuneata* Lindl. From Araucanía, Chile. *Gayana Botánica* 72: 145–148, https://doi.org/10.4067/S0717-66432015000100017

Ballari SA, Barrios-García MN (2014) A review of wild boar *Sus scrofa* diet and factors affecting food selection in native and introduced ranges. *Mammal Review* 44: 124–134, https://doi.org/10.1111/mam.12015

Barahona-Segovia R (2019) Conservación biológica de invertebrados en los bosques de la Cordillera de la Costa de Chile: amenazas y propuestas. In: Smith-Ramírez C, Squeo FA (eds), Biodiversidad y Ecología de los Bosques Costeros de Chile. Editorial Universidad de Los Lagos, Chile, pp 269–298

Barrios-García MN, Ballari SA (2012) Impact of wild boar (*Sus scrofa*) in its introduced and native range: a review. *Biological Invasions* 14: 2283–2300, https://doi.org/10.1007/s10530-012-0229-6

Bevins SN, Pedersen K, Lutman MW, Gidlewski T, Deliberto TJ (2014) Consequences associated with the recent range expansion of nonnative feral swine. *BioScience* 64: 291–299, https://doi.org/10.1093/biosci/biu015

Bratton SP (1975) The effect of the European wild boar, *Sus scrofa*, on gray beech forest in the Great Smoky Mountains. *Ecology* 56: 1356–1366, https://doi.org/10.2307/1934702

Burton AC, Neilson E, Moreira D, Ladle A, Steenweg R, Fisher JT, Bayne E, Boutin S (2015) Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. *Journal of Applied Ecology* 52: 675–685, https://doi.org/10.1111/1365-2664.12432

Castro-Carrasco C, Ortiz JC (2019) Updated of the taxonomy, distribution and richness of the amphibians species of the Nahuelbuta Range. In: Smith-Ramírez C, Squeo FA (eds), Biodiversidad y Ecología de los Bosques Costeros de Chile. Editorial Universidad de Los Lagos, Chile, pp 137–147

Echeverría C, Coomes D, Salas J, Rey-Benayas JM, Lara A, Newton A (2006) Rapid deforestation and fragmentation of Chilean temperate forests. *Biological Conservation* 130: 481–494, https://doi.org/10.1016/j.biocon.2006.01.017

García E, Mora L, Torres P, Jercic MI, Mercado R (2005) First record of human trichinosis in Chile associated with consumption of wild boar (*Sus scrofa*). *Memórias do Instituto Oswaldo Cruz* 100: 17–18, https://doi.org/10.1590/S0074-02762005000100003

González ME, Cortés M, Izquierdo F, Gallo L, Echeverría C, Bekessy S, Montaldo P (2006) *Araucaria araucana* (Molina) K. Koch. Araucaria (o), Pehuén, Pino piñonero, Pino de Neuquén, Monkey Puzzle Tree. In: Donoso C (ed), Las especies arbóreas de los bosques templados de Chile y Argentina autoecología. Marisa Cuneo Ediciones. Valdivia, Chile, pp 36–53

Gortázar G, Ferroglio E, Höfle U, Frölich K, Vicente J (2007) Diseases shared between wildlife and livestock: A European perspective. *European Journal Wildlife Research* 53: 241–256, https://doi.org/10.1007/s10344-007-0098-y

Jaksic FM (1998) Vertebrate invaders and their ecological impacts in Chile. *Biodiversity and Conservation* 7: 1427–1445, https://doi.org/10.1023/A:1008825802448

Jaksic FM, Iriarte JA, Jiménez JE, Martínez DR (2002) Invaders without frontiers: cross-border invasions of exotic mammals. *Biological Invasions* 4: 157–173, https://doi.org/10.1023/A:1020576709964

Lantschner MV, Rusch V, Hayes JP (2013) Do exotic pine plantations favour the spread of invasive herbivorous mammals in Patagonia? *Austral Ecology* 38: 338–345, https://doi.org/10.1111/j.1442-9993.2012.02411.x

Lowe S, Browne M, Boudjelas S, Poorter M (2000) 100 of the world's worst invasive alien species: a selection from the global invasive species database. The Invasive Species Specialist Group, Species Survival Commission, World Conservation Union IUCN, 12 pp

Massei G, Coats J, Lambert MS, Pietravalle S, Gill R, Cowan D (2018) Camera traps and activity signs to estimate wild boar density and derive abundance indices. *Pest Management Science* 74: 853–860, https://doi.org/10.1002/ps.4763

Mayer JJ, Brisbin IL Jr. (2008) Wild Pigs in the United States: Their History, Comparative Morphology, and Current Status. University of Georgia Press, USA, 313 pp

Moreira-Arce D, Vergara PM, Boutin S (2015a) Diurnal human activity and introduced species affect occurrence of carnivores in a human-dominated landscape. *PLoS ONE* 10: e0137854, https://doi.org/10.1371/journal.pone.0137854

Moreira-Arce D, Vergara PM, Boutin S, Simonetti JA, Briceño C, Acosta-Jamett G (2015b) Native forest replacement by exotic plantations triggers changes in prey selection of mesocarnivores. *Biological Conservation* 192: 258–267, https://doi.org/10.1016/j.biocon.2015.09.015

Nuñez MA, Hayward J, Horton TR, Amico GC, Dimarco RD, Barrios-Garcia MN, Simberloff D (2013) Exotic mammals disperse exotic fungi that promote invasion by exotic trees. *PLoS ONE* 8: e66832, https://doi.org/10.1371/journal.pone.0066832

Otavo S, Echeverría C (2017) Fragmentación progresiva y pérdida de hábitat de bosques naturales en uno de los hotspot mundiales de biodiversidad. *Revista mexicana de biodiversidad* 88: 924–935, https://doi.org/10.1016/j.rmb.2017.10.041

Palmer MS, Swanson A, Kosmala M, Arnold T, Packer C (2018) Evaluating relative abundance indices for terrestrial herbivores from large-scale camera trap surveys. *African Journal of Ecology* 56: 791–803, https://doi.org/10.1111/aje.12566

Peris A, Closa-Sebastià F, Marco I, Serrano E, Casas-Díaz E (2019) Baiting improves wild boar population size estimates by camera trapping. *Mammalian Biology* 98: 28–35, https://doi.org/10.1016/j.mambio.2019.07.005

Pysek P, Richardson DM (2010) Invasive species, environmental change and management, and health. *Annual Review of Environment and Resources* 35: 25–55, https://doi.org/10.1146/annurev-environ-033009-095548

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2000) Global biodiversity scenarios for the year 2100. *Science* 287: 1770–1774, https://doi.org/10.1126/science.287.5459.1770

Seward NW, VerCauteren KC, Witmer GW, Engeman RM (2004) Feral swine impacts on agriculture and the environment. *Sheep & Goat Research Journal* 19: 34–40

Skewes O, Jaksic FM (2015) History of the introduction and present distribution of the european wild boar (*Sus scrofa*) in Chile. *Mastozoología neotropical* 22(1): 113–124

Skewes O, Rodríguez R, Jaksic, JM (2007) Ecología trófica del jabalí europeo (*Sus scrofa*) silvestre en Chile. *Revista Chilena de Historia Natural* 80: 295–307, https://doi.org/10.4067/S0716-078X2007000300004

Smith-Ramírez C (2004) The Chilean coastal range: A vanishing center of biodiversity and endemism in South American temperate rainforests. *Biodiversity and Conservation* 13: 373–393, https://doi.org/10.1023/B:BIOC.0000006505.67560.9f

Smith-Ramírez C, Teillier S, Jiménez JE, Barahona-Segovia RM, Parra LE, Vera A, Jerez V (2019) In: Smith-Ramírez C, Squeo FA (eds), Biodiversidad y Ecología de los Bosques Costeros de Chile. Editorial Universidad de Los Lagos, Chile, pp 393–416

Troncoso-Palacios J (2019) Biodiversidad y conservación de reptiles de los bosques costeros de Chile. In: Smith-Ramírez C, Squeo FA (eds), Biodiversidad y Ecología de los Bosques Costeros de Chile. Editorial Universidad de Los Lagos, Chile, pp 149–166

Villagrán C (1990) Glacial climates and their effects on the history of the vegetation of Chile: a synthesis based on palynological evidence from Isla de Chiloé. *Review of Palaeobotany and Palynology* 65: 17–24, https://doi.org/10.1016/0034-6667(90)90052-K

Villagrán C, Armesto JJ (2005) Fitogeografía histórica de la Cordillera de la Costa de Chile. In: Smith-Ramírez C, Armesto JJ, Valdovinos C (eds), Historia, Biodiversidad y Ecología de los Bosques Costeros de Chile. Editorial Universitaria, Chile, pp 99–116

Waithman JD, Sweitzer RA, Van Vuren D, Drew JD, Brinkhaus AJ, Gardner IA, Boyce WM (1999) Range expansion, population sizes, and management of wild pigs in California. *Journal of Wildlife Management* 63: 298–308, https://doi.org/10.2307/3802513

Zivin J, Hueth BM, Zilberman D (2000) Managing a multiple-use resource: The case of feral pig management in California rangeland. *Journal of Environmental Economics and Management* 39: 189–204, https://doi.org/10.1006/jeem.1999.1101

Supplementary material

The following supplementary material is available for this article:

Table S1. Locations of Eurasian wild boar (*Sus scrofa*) and independent records (photos) from the Nahuelbuta Mountain Area (January 2018–February 2019).

Figure S1. Temporal activity of wild boar (*Sus scrofa*) in Los Alpes and Trongol Alto sites, Nahuelbuta Mountain Area (January 2018–February 2019).

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