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Notes on Geographic Distribution

Oryctolagus cuniculus Linneaus, 1758 (Mammalia: Lagomorpha: Leporidae): New record in the Nahuel Huapi National Park, Patagonia, Argentina

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Abstract: Biological invasions are difficult to control when invader's populations attain high densities; therefore early detection is important for implementing management strategies. This study presents the first record of the European rabbit, *Oryctolagus cuniculus* Linneaus, 1758, in Nahuel Huapi National Park, Patagonia, Argentina and confirms its dispersion in habitats adjacent to the Siete Lagos route. Considering the potential ecological consequences of rabbit in a protected area, the early detection of this invasive species will allow the National Park Administration to implement urgent control measures in order to stop the advance.

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Most studies on biological invasions are performed when populations attain high densities and successful controlling measures are difficult to implement. However, if detection is early and basic aspects of distribution, dispersion, and habitat use are known, it is possible to develop control strategies and prevent further spread. The European rabbit *Oryctolagus cuniculus* Linneaus, 1758, is a species native to southern Europe and northern Africa, and was introduced successfully in all continents except Antarctica and Asia (Smith and Boyer 2008). Rabbits are considered ecosystem engineers because their activities produce marked ecosystem-level effects. Construction of burrows alters soil structure and composition while selective feeding modifies richness and diversity of plant species (Eldridge and Myers 2001). Although rabbits have been extensively studied in their native and introduced ranges, in Patagonia the spread and effects of this herbivore on vegetation and wildlife remain understudied.

A high rate of biological invasion was recorded in the Nahuel Huapi National Park (NHNP) (Merino *et al*. 2009) where successful populations of invasive mammals are well established: red deer *Cervus elaphus* Linneaus, 1758, European hare *Lepus europaeus* Pallas, 1778, and wild boar *Sus scrofa* Linneaus, 1758. The exotic rabbit arrived at Lanin National Park in 1989 (Funes *et al.* unpublished data) and the most southwestern record corresponds to Meliquina Lake (40°22′39″ S, 71°18′ 89″ W) (Bonino and Sourigues 2009). The high rates of dispersal recorded for this species indicate a high probability of invasion throughout the Patagonian region, including the Andean forests in the Nahuel Huapi National Park (Bonino and Sourigues 2009).

The potential impacts of rabbits on native forests are little known. Studies in xeric habitats of central Chile showed several negative effects, *e.g.*, they affect distribution on native grasses by soil modification (Jaksic and Fuentes 1980), browse and consume shrub seedlings when herbs are scarce (Simonetti and Fuentes 1983), and destroy more seedlings than the native small mammals (Fuentes *et al*. 1983). At local landscape scale, studies conducted in native forests of *Nothofagus pumilio* showed that hare and rabbit browsing inhibit regeneration (Mutarelli and Orfila 1973; Veblen *et al*. 2004). Rabbits are also good seed dispersers of native and exotic plants and could facilitate seedling establishment (Fernández and Sáiz 2007; Castro *et al*. 2008). In addition, diet studies showed trophic competition with domestic livestock (Bonino and Soriguer 2009), and also trophic overlapping with the mountain vizcacha *Lagidium viscacia* Molina, 1782, which represents a threat to their colonies in situations of scarce food (Galende and Raffaele 2013a). These antecedents suggest that the presence of the European rabbit in the NHNP could have important influences on floristic composition, community structure, and native wildlife. The early detection, dispersion, and current status of rabbit populations are important to the National Park Administration in order to implement rapid control measures and prevent the spread of rabbits in Patagonian forests. The goal of this study is to confirm the presence and dispersal of rabbits in different plant communities of the Nahuel Huapi National Park. Routes of dispersion and potential ecological consequences of the rabbits in Patagonian ecosystems are also discussed.

This study was conducted in a mountain area at 1012 m a.s.l., in the northern edge of Nahuel Huapi National Park (40° 24′17.6″ S; 71°29′28.2″ W) (Figure 1). The subantarctic forest is dominated by tree species of *Nothofagus* spp. and *Autrocedrus chilensis*; the grasslands by *Stipa* spp., *Festuca pallescens*, wet meadows by *Juncus* spp., *Carex* spp.; and shrublands by *Berberis buxifolia* and the exotic rose *Rosa rubiginosa* (Mermoz *et al*. 2009). Based on observation records provided by the local park ranger,

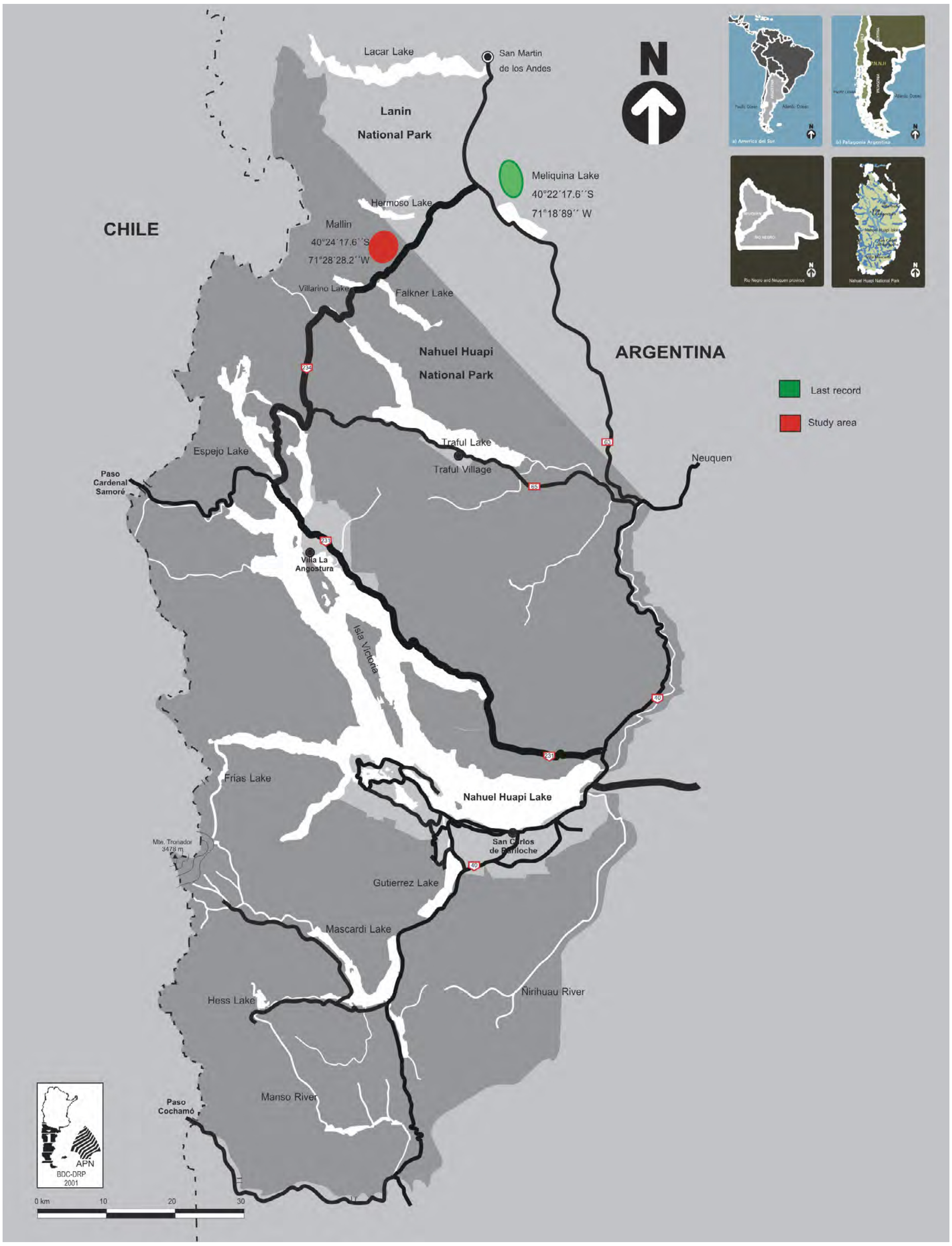

FIGURE 1. Early detection of European rabbit (*Oryctolagus cuniculus*) in Nahuel Huapi National Park, Patagonia Argentina.

we conducted a survey to detect rabbit presence and assess habitat use in the most common plant communities (forest, wet meadow and shrubland).

In seasonal samplings of autumn (May 2011), winter (August), spring (November), summer (March), and autumn 2012 (June), fresh fecal pellets were counted and collected in circular plots in the three most common plant communities: a) *Nothofagus antarctica* forest, b) shrubland of *Berberis buxifolia* and *Rosa rubiginosa*, and c) wet meadow of *Carex* spp. and *Juncus* sp. Rabbit fecal pellets were identified and differentiated from the pellets of the European hare by size, shape, color, texture, and vegetable fiber fragmentation (Figure 2). The relative abundance of rabbits per habitat type was estimated by fecal pellet count using two transects 300 m long with 30 fixed plots (sampling units = SU) of 1 m in diameter (total area = 0.78 m^2) at intervals of 10 m. Pellets were cleaned after each survey to avoid double counting. The average number of pellets/m^2 per habitat was estimated by the relative abundance index (PAI) (Ferreira and Alves 2009) considering number of pellets counted in 60 SU, and seasonal average by the number of pellets in 180 m^2 SU (X ± SE). The annual average density of pellets (PAI) was estimated using the seasonal average values in a total of 720 SU. Variations in pellet densities between habitat types were assessed by Kruskal-Wallis and Mann-Whitney nonparametric tests; seasonal differences by Friedman test for multiple dependent samples; and differences in mean densities of pellets between beginning and end of the study were evaluated by the Wilcoxon test (Zar 1999).

Figure 2. a: Fecal pellets of European rabbit (*Oryctolagus cuniculus*); b: European hare (*Lepus europaeus*)

Rabbit presence was confirmed in forests, shrublands, and wet meadows in northern NHNP. Fecal pellets were more abundant in meadows adjacent to Siete Lagos route (47% of sampling units) than in shrublands and forests (39 and 14% of sampling units respectively, Figure 3).

The annual average density of pellets was low (0.26 ±0.11), and decreased significantly (Z = 4.40 p <0.001, Wilcoxon test) throughout the annual cycle from autumn 2011–2012. The mean pellet density during the study showed no significant variations between seasons (ANOVA Friedman test = 8, DF= 4, p = 0.09) and between habitats ($F_{2, 15}$ = 1.57, p = 0.45, Kruskal-Wallis test).

Seasonal analysis showed that in autumn 2011, the greatest annual pellets/m^2 density was recorded in wet meadows (1.07 ± 0.26) and pellets density differed significantly between habitats ($F_{2, 180}$ = 6.0, p = 0.04). In winter 2011, the Caulle volcano erupted covering the whole area with a layer of ashes, and after this event fecal pellets were not detected in the study area. In the following spring there were no significant differences in pellet abundances between habitats ($F_{2, 180}$ = 3.35, p = 0.18). In summer and autumn 2012, there were no fecal pellets in forest and the records in shrublands and wet meadows showed no significant differences (summer, U = 1795, p = 0.98, autumn U = 1640, p = 0.40, Mann-Whitney test).

In agreement with predictions by Bonino and Soriguer (2009), the results confirmed that rabbits are actively spreading southwards into Patagonia. They are currently present at 25 km from the previous southernmost record and inhabit shrublands, forests, and wet meadows adjacent to Siete Lagos route in the Nahuel Huapi National Park. Presence of fecal pellets in these areas coincide with high advance rates previously observed in this route (Funes *et al*. unpublished data) confirming that river corridors and adjacent areas to roads functioned as favorable ways for dispersion (Bonino and Soriguer 2009; Cuevas *et al.* 2011). In some areas of northern Patagonia, rabbit density is high (39–57 rabbits/ha) and the average rate of dispersion varied between 6 and 9 km/year according to the river basin considered (Bonino and Soriguer 2009). The relative low abundance recorded in this study was similar to that of some regions in Portugal and Spain (Ferreira and Alves 2009), but these results should be taken with caution because in June 2011 the Puyehue Caulle volcano erupted. This geological event had a strong local impact because the study area was covered with ≈20 cm of ashes. Estimations for ash values indicated that food availability could be reduced between 30–50% (Siffredi et al. 2011). Despite this, the presence and numerical recovery of rabbit population in the following spring, demonstrated their great plasticity for surviving extreme conditions and invading diverse environments (Bonino and Soriguer 2009; Ferreira and Alves 2009; Cuevas *et al*. 2011). Probably the decrease in rabbit abundance throughout this study was due to reductions in food resources as was observed in Europe (Ferreira and Alves 2009, Moreno and Villafuerte 1995).

Regeneration of *Nothofagus* sp. and *Austrocedrus chilensis* native forests is frequently affected by grazing from livestock, red deer, hare, rabbit, and rooting disturbances by wild boar (Relva *et al*. 2010, Veblen *et al*. 2004; Barrios García and Ballari 2012). In contrast, strong evidences in this region indicated a facilitator effect by red deer and wild boar for the establishment of exotic plants (Relva *et al*. 2010; Barrios Garcia and Simberloff 2013). These impacts, in addition to rabbit effects, could have synergistic effects facilitating the settlement of exotic plants although field experiments are still needed. Rabbits are also known for their negative impacts on native fauna. In general, they compete for food and shelter with other herbivores or can cause an increase in carnivore populations (GISD 2005). In northern Patagonia, the native mountain vizcacha (Lagidium viscacia) and rabbit coexist in rocky outcrop areas and their diets based on grasses showed a trophic overlap (Galende and Raffaele 2013a). The vizcacha is a rock specialist with activities restricted to rocky proximity and highly vulnerable to changes in food availability (Galende and Raffaele 2013b). Although the major impact of rabbits occurs in the vegetation around burrows, they prefer to feed on grasses, and also remove palatable plants at distances from the burrows (Eldridge and Myers 2001; Galvez-Bravo *et al.* 2011). In food scarcity situations, such as in winter and/or high densities of rabbits, vizcacha populations could be threatened.

Additionally, soil modifications by rabbits could also affect the burrows of fossorial native rodents as the tuco-tuco (*Ctenomys* spp.).

The results of this study indicate that rabbit dispersion continues and currently reaches the Nahuel Huapi National Park. This represents a new challenge for biodiversity conservation in protected areas of Patagonian region where the highest relative rates of invasion of the country were recorded (Merino *et al.* 2009). In the NHNP, the invasive vertebrate species management program (APN Disposition 373/10) indicates regulated hunting for other exotic species such as red deer and wild boar. Therefore, similar measures could be considered to reduce rabbit populations.

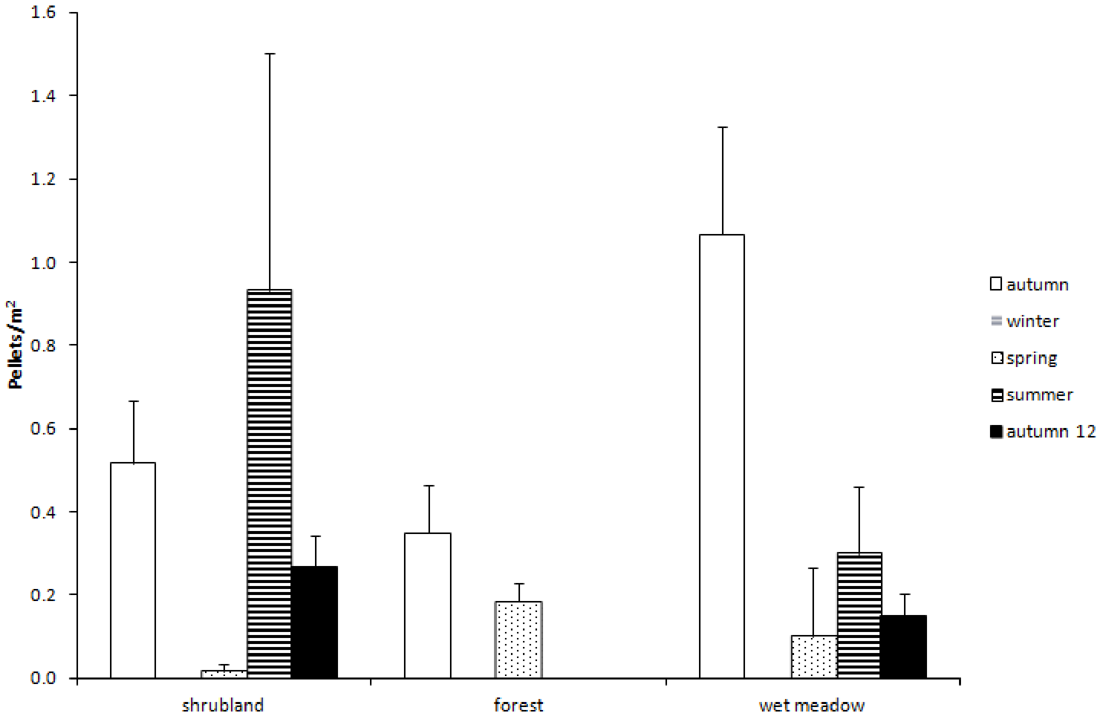

Figure 3. Seasonal variation of European rabbit (*Oryctolagus cuniculus*) fecal pellets on three plant communities in Nahuel Huapi National Park, Patagonia Argentina. Values represent mean pellet density per square meter (± SE). Winter is the season following the volcanic eruption.

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