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Short Communication

Anthropogenic and environmental effects on invasive mammal distribution in northern Patagonia, Argentina

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ABSTRACT

Anthropogenic disturbance is an important factor influencing biological invasions. The European hare (*Lepus europaeus*) and wild boar (*Sus scrofa*) are invasive species known to cause substantial environmental damage, and were introduced to Argentina during the early 1900s. We compared the relative importance of anthropogenic and environmental factors in hare and boar occurrence in Nahuel Huapi National Park, Argentina, and assessed the hypothesis that invasion can occur regardless of anthropogenic disturbance. Also, we assessed whether hare and boar occupancy offered support for the disturbance hypothesis, which states that invasive species are facilitated by anthropogenic disturbance. We deployed 80 cameras from February to May 2012 and January to April 2013 and at each site measured three environmental (land cover, horizontal cover, and percentage herbaceous vegetation) and three anthropogenic (distance to nearest human settlement, distance to nearest road, and average daily number of people) variables. We used likelihood-based occupancy modeling to estimate site occurrence and detectability. We obtained 480 independent detections of hares and 134 of boars in 1680 camera days. Environmental factors had a greater effect on hare occupancy than anthropogenic disturbances, and hare occupancy was greater in more open areas and closer to human settlements, supporting both hypotheses. Boar occurrence was equally influenced by anthropogenic and environmental factors, and offered mixed support for both hypotheses; boars were present only in humid land covers, and occupancy was lesser closer to settlements but greater closer to roads. Species responses to anthropogenic and environmental factors can vary based on life history traits and role in human society. Identifying the effect of environmental factors and human disturbances on species is fundamental for allocating limited resources in management and conservation.

Few ecosystems are free of introduced invasive species, and an increasing proportion of habitats are becoming dominated by them (Pyšek and Richardson 2010). A major component of biological invasions is anthropogenic disturbance (Nuñez and Pauchard 2010), which can act as a facilitating agent at local and global scales (Meyerson and Mooney 2007). Evidence of human disturbance benefiting invaders has been found for many communities, including freshwater fish and algae (Johnson et al., 2008), marine invertebrates (Crooks et al. 2011), and grassland plants (Kalwij et al. 2008). The benefit of disturbance on invasive species can result from the avoidance or reduction in the intensity of biotic resistance, manifested through decreased interspecific competition or predation in the invaded community (Elton 1958; Hobbs and Huenneke 1992), which would in turn result in increased survival and spread.

Several mammal introductions have occurred in the Patagonian region of South America, which then have become invasive (Merino et al. 2009). Particularly, introduced herbivores have been found to disturb the establishment and growth of native vegetation (e.g. Vazquez 2002; Veblen et al. 1992), and decrease native herbivores' access to resources (e.g. Galende and Grigera 1998). The European hare (*Lepus europaeus*) and wild boar (*Sus scrofa*) are invasive species introduced to Argentina during the early 1900s (Novillo and Ojeda 2008) and are the two most widespread invasive species in the National Parks System of Argentina (Merino et al. 2009). Boars were introduced to Argentina from a Siberian Russian stock (Pescador et al. 2009) and hares from European stock, most likely France (Carman 1976 in Bonino et al. 2010); consequently, based on latitude, these species can be considered broadly adapted to the temperatures and seasons occurring in southern Argentina.

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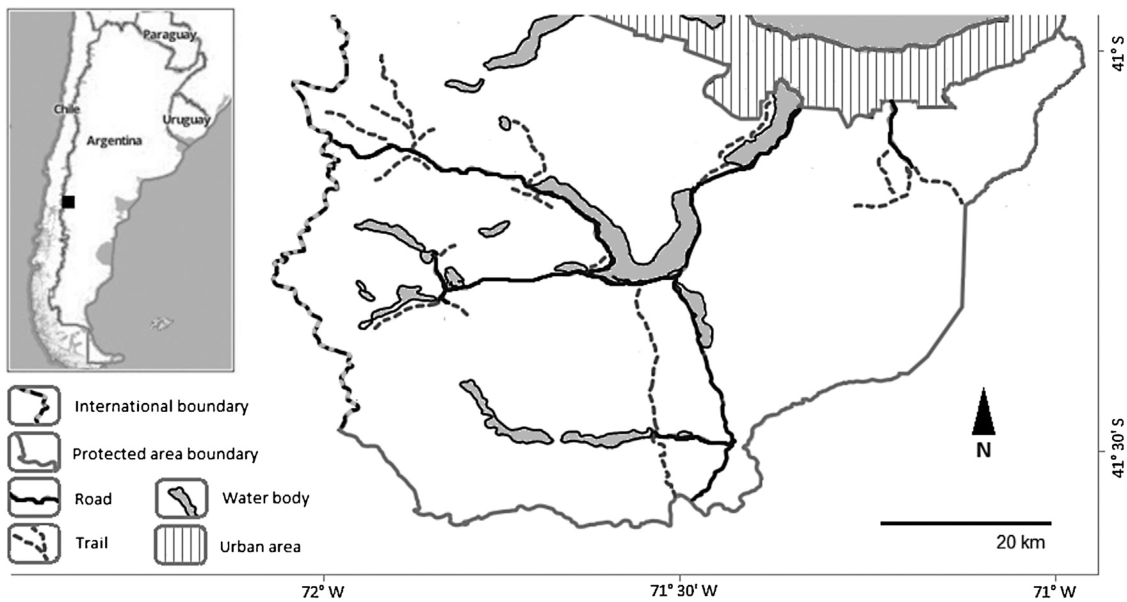

Fig. 1. Location of Nahuel Huapi National Park, Argentina (solid black square; inset), and study area (southern portion of the national park). Camera traps were located approx. 1 km apart along all trails shown, during February–May 2012 and January–May 2013.

We compared the relative importance of anthropogenic disturbances and environmental factors on the distribution of European hares and wild boars in Nahuel Huapi National Park, Argentinian Patagonia. We assessed support for the hypothesis than successful colonization can happen irrespective of human influences, provided natural conditions are met. Hence, occupancy should be more heavily influenced by environmental factors than anthropogenic disturbances. Alternatively, we assessed how anthropogenic disturbance can influence invasive mammals in this area, supporting Elton's disturbance hypothesis (Elton 1958) which states that human alterations of the environment facilitate invasive species. As a result, human disturbance would be a positive driver of hare and boar distribution, causing occupancy to be greater closer to human development, such as roads, settlements, and touristic areas.

The study area was in the southern portion of Nahuel Huapi National Park, Argentina (Fig. 1). There are three primary ecological regions in the park based on annual precipitation and elevation: Altoandino, Andino-Patagonico, and Patagonian steppe (Veblen et al. 1992). We deployed cameras in the Andino-Patagonico region, which comprises transitional forests and shrublands from 700 to 1700 m elevation with annual precipitation varying from 600 to 1200 mm. Dominant trees include ñire *Nothofagus antarctica*, cohiue *N. dombeyi*, and lenga *N. pumilio* (IUCN, 1982; Veblen et al. 1992). All places surveyed corresponded with public areas in the national park used for tourism.

We established 80 camera sites that were surveyed for 21 days by one infrared camera (Bushnell 8MP Trophy Cam Night Vision Trail Camera, Bushnell, Kansas, USA). Sites were positioned about 1 km apart along hiking trails from 700 to 1600 m elevation during February to May 2012 and January to April 2013, representing about 60% of available hiking trails in the southern section of the park and 90% of the elevational gradient (Fig. 1). In each camera site, we recorded the location with a GPS device (Garmin eTrex, Garmin International, Inc., Olathe, Kansas, USA) and we measured three environmental (land cover, horizontal cover, and percentage of herbaceous vegetation) and three anthropogenic (distance to nearest human settlement, distance to nearest road, and average daily number of people) variables. We assigned each camera site to one of three land covers (*N. dombeyi*, *N. antartica* or *N. pumilio*) to represent broad scale vegetation community, using as reference a vegetation map of the park (Res.: 500 m; Mermoz and Martín, 1987). We estimated horizontal cover to represent vegetation density using the cover cylinder method, modified from Ordiz et al. (2009). At each point, we placed a white fabric and steel spring wire cylinder (50 cm high by 30 cm diameter) and measured the minimum sighting distance (D; the minimum distance at which the cylinder can no longer be seen) in the four cardinal directions. We took measurements at a height of 40 cm to mimic eye level of a medium-sized mammal. We then calculated the mean cover value for each point by averaging the four values. We measured herbaceous vegetation (i.e. percentage of herbs and grasses) to represent food availability for hares. We took measurements in each cardinal direction 5 meters from the camera and directly under it. We placed a wooden square (30×30 cm) divided with wire into 9 10×10-cm squares and counted the number of smaller squares with >50% cover. We converted the number of smaller squares with >50% cover to a percentage and averaged percentages from the 5 locations. We measured distance to nearest human settlement and road using satellite images (Google Earth, Google Inc., Mountain View, California, USA) and calculated the mean daily number of people from camera detections at each site.

After the surveys, we identified mammals in images to species. For each site, we created an encounter history using three 7-day survey periods, for a total of 21 days. We used single single-season likelihood-based occupancy modeling (MacKenzie et al. 2002) using program PRESENCE 6.2 (Hines 2006; MacKenzie et al. 2005) to estimate site occurrence (probability that the species occurred at a site) and detectability (probability that the species was detected if present) from detection-non detection data. We first tested for correlation between variables ($r > 0.7$; Dormann et al. 2013) and evaluated if season (i.e. 2012, 2013) had an effect in detection probability. For the following analysis, we used the six variables collected as covariates in the occupancy models for hares, and all covariates except herbaceous vegetation for boars. To compare the relative influence of anthropogenic and environmental factors on hare and boar occupancy, we compared four models: environmental (all environmental covariates), anthropogenic (all anthropogenic covariates), global (all covariates) and null model for each species. We ranked these models for parsimony using AIC with adjustment for small sample sizes (AICc; Burnham and Anderson