THE INTRODUCED SILVER PHEASANT (*LOPHURA NYCTHEMERA*) IN PATAGONIA: ABUNDANCE, GROUP STRUCTURE, ACTIVITY PATTERNS AND ASSOCIATION TO HUMAN DISTURBANCE

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ABSTRACT.— Phasianids are one of the groups of introduced birds with highest impact on native ecosystems. In Patagonia several phasianids are established or in process of establishment, thus it is relevant to know their impacts on ecosystems. The Silver Pheasant (*Lophura nycthemera*) was introduced to Isla Victoria in the 1950's and successfully established all over the island. The aim of this work is to study the population of this species on Isla Victoria in terms of abundance and association to human disturbance as a first step to know its potential impact in the ecosystem. We conducted camera-trapping and direct observations in linear transects located in highly disturbed and in lowly disturbed areas. Using camera-trapping data we estimated an index of relative abundance to compare habitat use between areas. We used the distance-sampling approach to estimate population density with the data from direct observations. The Silver Pheasant used much more frequently areas with a high level of disturbance, suggesting that the presence of disturbed habitats could facilitate establishment and spread of this species in Patagonia. Population densities in areas with high and with low levels of disturbance were higher than those reported from the native distribution area, showing that the Silver Pheasant had a great success on Isla Victoria. The high abundance, together with distinctive characteristics such as a large body size, foraging habits and social behaviour can shape the interactions with native species and influence its impact on native communities.

KEY WORDS: *habitat use, Isla Victoria,* Lophura nycthemera*, phasianids, Silver Pheasant.*

RESUMEN. EL FAISÁN PLATEADO (*LOPHURA NYCTHEMERA*) INTRODUCIDO EN LA PATAGONIA: ABUNDANCIA, ESTRUCTURA DE LOS GRUPOS, PATRONES DE ACTIVIDAD Y ASOCIACIÓN CON EL DISTURBIO HUMANO.— Los fasiánidos son uno de los grupos de aves introducidas con mayor impacto en los ecosistemas nativos. En la Patagonia varias especies de fasiánidos están establecidas o en proceso de establecimiento, por lo que es relevante conocer sus impactos sobre los ecosistemas. El Faisán Plateado (*Lophura nycthemera*) fue introducido en Isla Victoria en la década de 1950 y se estableció exitosamente en toda la isla. El objetivo de este trabajo es estudiar la población de esta especie en Isla Victoria en términos de abundancia y su asociación con el disturbio humano como un primer paso para conocer su impacto potencial en el ecosistema. Se realizaron capturas fotográficas mediante fototrampeo y observaciones directas en transectas lineales ubicadas en áreas con niveles alto y bajo de disturbio humano. Con los datos de las capturas fotográficas se estimó un índice de abundancia relativa para comparar el uso de hábitat entre las dos áreas. Se utilizó la técnica de muestreo a distancia para estimar la densidad poblacional a partir de las observaciones directas. El Faisán Plateado usó más las áreas con un alto nivel de disturbio, lo que sugiere que la presencia de hábitats modificados podría facilitar su establecimiento y dispersión en la Patagonia. Las densidades poblacionales, tanto en las áreas con alto como con bajo nivel de disturbio, fueron mayores que las reportadas en su área de distribución nativa, mostrando que esta especie ha tenido un gran éxito en Isla Victoria. La alta abundancia, junto con características distintivas tales como el gran tamaño, los hábitos de alimentación y el comportamiento social, pueden moldear las interacciones con las especies nativas e influenciar su impacto sobre las comunidades nativas.

PALABRAS CLAVE: *Faisán Plateado, fasiánidos, Isla Victoria,* Lophura nycthemera*, uso de hábitat.*

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In Patagonia, southern Argentina and Chile, biological invasions of terrestrial animals are a widely recognized problem, even in national parks (Jaksic et al. 2002). This region has recorded the highest invasion indexes of non-native mammals from protected areas in Argentina (Merino et al. 2009). Some terrestrial communities in Patagonia are even dominated by non-native vertebrates (Gantchoff and Belant 2015, Martin-Albarracin et al. 2015b). To understand the impacts of these biological invasions on native communities it is necessary to know the abundance of these species and how they interact with the environment and with native species and communities.

There are several species of non-native birds successfully established in Argentina. The most abundant species are the House Sparrow (*Passer domesticus*), the Rock Pigeon (*Columba livia*) and the European Starling (*Sturnus vulgaris*). The first two species are distributed along the entire country, whereas the European Starling is associated to the central region of Argentina and currently in process of expansion (Navas 2002, Peris et al. 2005). In Patagonia several phasianids are established or in process of establishment, such as the Silver Pheasant (*Lophura nycthemera*), the Ring-necked Pheasant (*Phasianus colchicus*) and the California Quail (*Callipepla californica*) (Couve and Vidal 2003, Matarasso and Salaberry 2008). In contrast to other invasive birds that are strongly associated to human populations, phasianids invade natural ecosystems, and several species have antecedents of invasion across the world (Lever 2005). The success of phasianids in establishing themselves in novel areas could be associated to a greater effort of introduction, because this family is over-represented in global patterns of bird introductions (Blackburn and Duncan 2001). Other hypotheses that could explain their success include enemy release (Elton 1958, Maron and Vilà 2001) or disturbance hypothesis (Elton 1958). In addition, phasianids are among the three avian families with highest impact on natural ecosystems at a global level (Martin-Albarracin et al. 2015a). Their known impacts include hybridization with closely related species, transmission of diseases to native species, and interaction with other invasive species. It is relevant to study their potential impact on native ecosystems in Patagonia. To achieve this, a first step is to study their abundance and their association to the environment and to resident species.

Here we will focus on the Silver Pheasant, a species that was introduced to Isla Victoria (Nahuel Huapi National Park) in the 1950s (Simberloff et al. 2003) and is currently naturalized and distributed all over the island (Martin-Albarracin, pers. obs.). No studies on the ecology of the Silver Pheasant have been conducted in this area. In the temperate forests of Patagonia, including Isla Victoria, native ground-foraging birds are much smaller in size and have a narrow diet breadth, so they can be negatively affected by the presence of the Silver Pheasant. The aim of this work is to study this species on Isla Victoria in terms of population density and association to areas with different levels of human disturbance. We will also explore some aspects of the biology of the Silver Pheasant: structure of family groups, daily activity patterns and interactions with native species.

METHODS

Study area

Isla Victoria is located in the central area of the Nahuel Huapi National Park, Argentina (40°57'S, 71°33'W; Fig. 1). The island is located in the middle of Nahuel Huapi Lake, a glacial lake with a surface of 557 km^2 found at an altitude of 770 masl. The island has a surface of 31 km^2 and a maximum altitude of 1050 masl. Climate is cold-temperate with a pronounced seasonality. Vegetation is dominated by forests of native *Nothofagus dombeyi* (coihue) and *Austrocedrus chilensis* (ciprés), and mixed shrublands of *Chusquea culeou* (caña colihue), *Berberis* spp. (michay) and *Aristotelia chilensis* (maqui). The assemblage of terrestrial mammals and birds is very simple (Martin-Albarracin et al. 2015b) and the main predators of the continental area surrounding the island, like puma (*Puma concolor*) and red fox (*Lycalopex culpaeus*) are not found on the island.

Since early 20th Century, Isla Victoria has been the focus of many plant and animal introductions, the majority of them conducted for economic purposes. In 1925, the Argentine government established a nursery to grow forestry and fruit trees (Koutché 1942). Among introduced plants there are at least 73 conifer species and 62 broadleaved trees (Simberloff et al. 2003). Several vertebrate species were deliberately introduced to the island, including three deer species and at least six phasianids (Daciuk 1978). Three of these species successfully established on the island: red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and the Silver Pheasant. Other vertebrates reached the island and managed to establish, for example American mink (*Neovison vison*), wild boar (*Sus scrofa*) and feral cat (*Felis silvestris*). The current vertebrate community of the island is highly dominated by non-native species (Martin-Albarracin et al. 2015b).

Study species

The Silver Pheasant is native from southeastern Asia, where it extends from the mountains of southern China southward to eastern Burma and most of Indochina; it is also present on the island of Hainan (Johnsgard 1986). It was introduced to Isla Victoria in the 1950's through several releases spanned over several years, and successfully established and spread all over the island.

This pheasant inhabits evergreen forests and bamboo thickets, up to an altitude of around 2150 masl (Brazil 2009). It has an omnivorous diet that includes insects, flowers, fruits, seeds, leaves and stems, small reptiles and worms. During the winter it subsists on grains, roots, underground stems and bulbs (Johnsgard 1986). Its longevity is of approximately 12 years. This species is polygynous: groups have typically 2–5 females per male (forming a harem) and remain together throughout the year (Johnsgard 1986, Savini and Sukumal 2009). In captivity, females produce clutches of 4–14 eggs and the incubation period is of 25–26 days. During the first two weeks after their hatching, only the female cares for the chicks. Later she takes them to join her mate and his harem until they are completely independent. However, if something happens to the female, the male assumes parental responsibilities. Two years are needed to achieve the full plumage and sexual maturity (Johnsgard 1986).

Although little information is available for the Silver Pheasant, the home range size of the Siamese Fireback (*Lophura diardi*) in evergreen forest habitat oscillates between 10–40 ha (Sukumal et al. 2010), and that of the Bornean Crested Fireback (*Lophura ignita*) was estimated in 20–25 ha in lowland forest habitat (Davison 1981, cited in Sukumal et al. 2010). In his native distribution area, the Silver Pheasant coexists in sympatry with the Siamese Fireback (Round and Gale 2008, Sukumal and Savini 2009). Although there are altitudinal differences between the habitats of these species (Sukumal and Savini 2009), sometimes they interact forming mixed groups (Savini and Sukumal 2009), but they can also interfere with each other and have aggressive behaviours (Praditsup et al. 2007). The Silver pheasant is also sympatric with other pheasant species that are potential competitors, such as the Mrs. Hume's Pheasant (*Syrmaticus humiae*) (Li et al. 2010). Its predators in the native area include leopard cat (*Prionailurus bengalensis*) and Siberian weasel (*Mustela sibirica*) (Li et al. 2010).

Sampling

We conducted fieldwork over areas with both high and low levels of human disturbance (Fig. 1). Approximately 50% of the

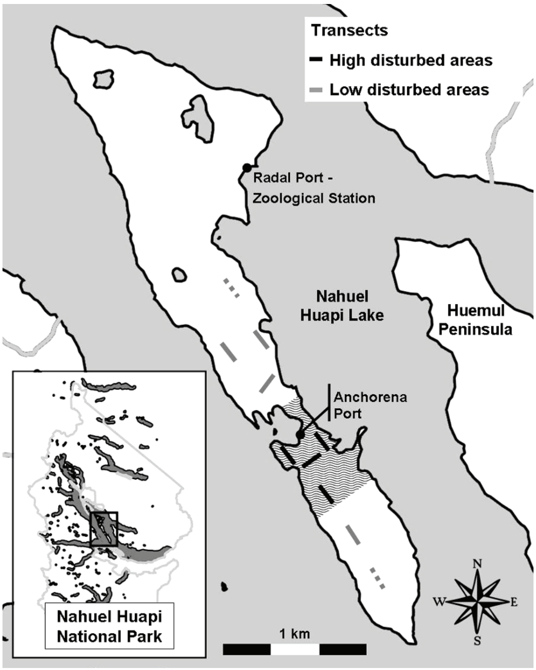

Figure 1. Map of Isla Victoria and its location in the Nahuel Huapi National Park, Argentina. Shadowed area surrounding Anchorena Port has a high level of human disturbance, while the rest of the island has a low level of disturbance. Solid lines show the location of transects used for camera-trapping and direct observations; dashed lines show the location of transects only used for direct observations.

island surface (16 km^2) was covered by fieldwork. Areas with high level of disturbance are surrounding Anchorena Port and include plantations of introduced conifers and eucalyptus and neighbouring areas dominated by shrublands highly invaded by non-native plant species. Highly disturbed areas also include human settlements (currently nine permanent residents) and are characterized by their intensive use. They are daily visited by tens to one thousand people that visit the island doing sightseeing tours. Areas with a low level of disturbance, in contrast, are dominated by native forests and shrublands. The human use there is limited, being sporadically visited by park rangers and people inhabiting or working on the island. Levels of invasion by non-native trees and shrubs in these regions are low.

We deployed 10 transects 500 m long: 4 transects were located in highly disturbed and 6 transects in lowly disturbed areas (Fig. 1). Transects were associated to paths used by park rangers (and in highly disturbed areas also by visitors), and separated from each other by at least 700 m. We used two complementary techniques to study pheasant populations that allowed us to evaluate different aspects of their ecology: camera-trapping and direct observations. Camera-trapping was used to study the use of areas with different levels of human disturbance, to describe daily activity patterns, to study the size and structure of familiar groups and to detect interactions with native species. Direct observations, meanwhile, allowed us to estimate population density and as a complementary way to study the size and structure of familiar groups. Camera-trapping was conducted across 8 transects (4 in each area) and direct observations were conducted in all transects (Fig. 1).

We used eight camera-traps with heat and motion sensors: six of the model Bushnell Trophy Cam 119736C and the other two of the model Stealth Cam Unit IR. Cameras were placed periodically one at each transect, installed at a height of 30–50 cm and programmed to take videos 40 s long with 1 min delay between two consecutive captures. The exact location of cameras along each transect was randomly determined, but we avoided looking for animal trails to avoid biases in the number of captures obtained (Rowcliffe et al. 2008). Camera traps remained installed on the field since June 2011 to May 2012. After 2–5 weeks, videos were downloaded and cameras were relocated randomly along the same transects. Each period of continuous trapping of one camera in one period was called "trapping event". The overall sampling effort was of 1253 camera-days, with a mean of 157 camera-days per transect (minimum: 86, maximum: 289).

Direct observations were conducted in January–March of 2012 and 2013. Transects were walked 3–5 times (only once a day) recording all individuals or groups of pheasants detected (seen or heard), and their perpendicular distance to the center of the transect (Buckland et al. 2001). We kept an average speed of walking of 2 km/h to detect as many animals as possible, minimizing the possibility of double-counting. Observations were conducted during the time periods of highest activity of pheasants (based on camera-trapping activity profiles). Whenever possible, we recorded the group size and composition. Individuals were classified as adult female, adult male, juvenile and chick.

Data analyses

To study pheasant habitat use, we calculated a relative abundance index in areas with high and low levels of human disturbance. This index was calculated as the number of independent captures got through camera-trapping multiplied by 100 and divided by trapping effort (Jenks et al. 2011). We considered that captures were independent when there was a difference of at least one hour between consecutive captures (following Bowkett et al. 2008). Trapping effort was defined as the total number of days that cameras remained active in the field. One value of the index was calculated for each level of disturbance, adding up the captures and the trapping effort of all cameras in an area. To get the variance of the index in each level of disturbance we used the bootstrapping technique. We conducted 1000 random samplings with replacement of trapping events for each level of disturbance, and for every resampling we calculated the value of the index (Rowcliffe et al. 2008). Values were compared through a non-parametric Kruskal-Wallis test by ranks.

Video captures obtained were classified according to the season (summer and winter)

Table 1. Total number of independent captures of terrestrial vertebrates obtained using camera-trapping in Isla Victoria (Nahuel Huapi National Park, Argentina).

	Captures
Birds	
Silver Pheasant (*Lophura nycthemera*) [a]	222
Chucao Tapaculo (*Scelorchilus rubecula*)	1
Mammals	
Red deer (*Cervus elaphus*) [a] and fallow deer (*Dama dama*) [a]	393
Wild boar (*Sus scrofa*) [a]	80
Feral domestic cat (*Felis silvestris*) [a]	9
American mink (*Neovison vison*) [a]	4
Long-tailed colilargo (*Oligoryzomys longicaudatus*)	1

[a] Non-native species.

and were used to generate a profile of daily activity pattern of birds. We recorded the exact time of the day in which the camera captured the video and we adjusted a circular kernel density function for capture times in each season using the package *activity* in the software R (R Core Team 2014, Rowcliffe et al. 2014). In addition, we classified detections according to the time of the day (morning, noon, evening and night) and conducted a Chi-squared test of independence to test whether the frequencies of detections at each time of the day differed among seasons. Periods were divided as follows: 05:30–12:30 (morning), 12:30–14:30 (noon), 14:30–21:30 (evening), and 21:30–05:30 (night) in summer; 09:00–12:30, 12:30–14:30, 14:30–18:30, and 18:30–09:00 in winter. Videos in which interactions with native species were recorded were carefully analyzed to identify the species involved and the interaction observed.

Population density was estimated from direct observations using the distance sampling approach (Buckland et al. 2007). For these analyses, perpendicular distances were truncated at 0, 5, 10, 15, 20, 30 and 50 m. We adjusted the half-normal and hazard-rate key functions to truncated data of distances to model the detection probability. Functions were adjusted considering each group of individuals as one detection. We used the level of disturbance (high or low) as the categorical predictive variable for population density. We used the Akaike Information Criterion together with goodness of fit tests to choose between models. We used average observed group size as an estimation of the expected group size to calculate population densities of birds (Buckland et al. 2001).

To study the size and structure of familiar groups from camera traps, independent video captures or sequences of video captures were carefully analyzed to identify all members of a group. Through direct observations we could also determine in detail the composition of some of the detected groups.

RESULTS

The results show that the Silver Pheasant successfully established on Isla Victoria, and that it has become one of the dominant terrestrial species. It was among the three terrestrial species more frequently captured by cameras. We got a total of 710 independent captures of 8 species of mammals and birds (Table 1). The great majority of captures (99.7%) were of non-native species, being the most abundant the red and the fallow deer, the Silver Pheasant and the wild boar. The Silver Pheasant was more abundant in areas with a high level of human disturbance than in areas with a low level of disturbance ($KW = 1499.25$, df = 1, $P < 0.001$; Fig. 2).

In the study area the range of daylight widely oscillates between summer and winter seasons. In midsummer the sun rises around 05:30 h and sets around 21:30 h, while in midwinter the sun rises around 09:00 h and sets at 18:30 h approximately. Daily activity pattern of the Silver Pheasant was strictly diurnal, with peaks of activity at dawn and at

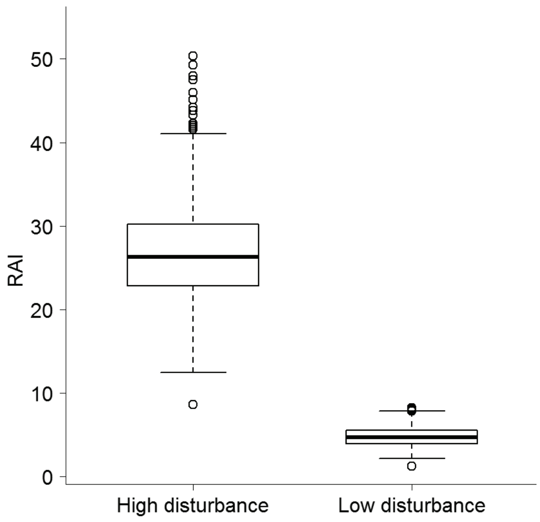

Figure 2. Differences in the relative abundance index (RAI) of Silver Pheasant (*Lophura nycthemera*) between sites with high and low levels of human disturbance in Isla Victoria (Nahuel Huapi National Park, Argentina). Each box contains the central 50% values of 1000 estimations of the index calculated from bootstrapped trapping events, the horizontal line inside the box shows the median value, and white points represent outliers.

Table 2. Model selection of the detection function in distance sampling analysis of Silver Pheasant (*Lophura nycthemera*) in Isla Victoria (Nahuel Huapi National Park, Argentina). Values of Akaike Information Criterion (AIC) and the results of the goodness of fit test for the models fitted to distance data are shown. The half-normal and hazard-rate key functions with cosine (COS) adjustment terms up to order 3 were fitted to truncated data of distances to model the detection function. The table shows only the best model for each key function.

Model	AIC	*P*	df
Hazard-rate	97.6	0.2725	3
Half-normal, COS(2)	106.605	0.0090	3

sunset (Fig. 3). We found no differences in the frequencies of detections at morning, noon, evening and night between seasons ($\chi^2 = 0.38$, df = 3, $P = 0.94$).

By direct observations we detected 33 independent groups of pheasants. The best model for the detection function used the hazard-rate key function (Table 2, Fig. 4). Population density was three times higher in areas with a high level of human disturbance than in areas with a low level of disturbance (5.69 vs 1.77 ind/ha, respectively).

We got 12 records of pheasant groups from camera-trapping videos and 10 records from direct observations. Familiar groups were composed by 1–6 individuals, occasionally up to 12 (mean: 3.82, SE: 0.58). The overall structure of groups was 1 adult female and 1–3 adult males. On two occasions (9%) we observed solitary males and on three occasions (14%) groups of 2 and 4 males. Thirty-six percent of groups had, in addition, 1–4 juveniles, and on one occasion we recorded a group of 4 adults with 8 chicks. Although several groups had more than 1 adult male, there was always a stronger male that was the leader of the group.

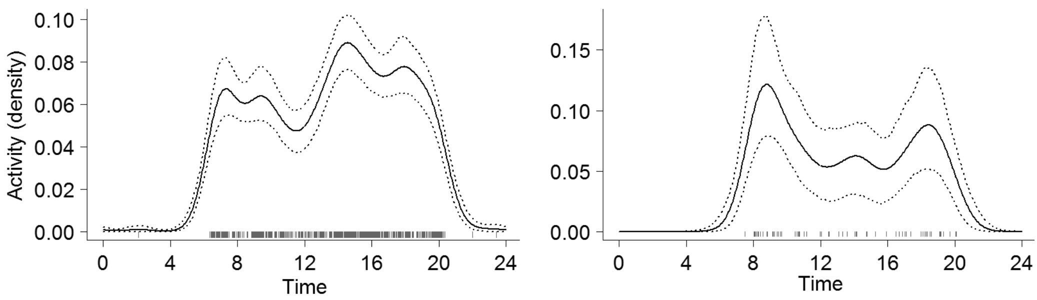

Figure 3. Activity patterns of Silver Pheasant (*Lophura nycthemera*) along the day in summer (left) and winter (right) in Isla Victoria (Nahuel Huapi National Park, Argentina). Adjustment curves of the circular kernel model for activity based on the density of captures are shown. The area under the curve adds up to one. Dashed lines limit the 95% confidence intervals. Grey lines on the bottom of each plot represent the frequency of captures through camera-trapping.

We detected aggressive interactions between the Silver Pheasant and native species in two occasions: in the first with a couple of Chimango Caracara (*Milvago chimango*) and in the other with a Black-faced Ibis (*Theristicus melanopis*).

DISCUSSION

Population density estimations obtained in this work (1.77 ind/ha, 5.69 ind/ha) are very high when compared to those obtained in the native range of the Silver Pheasant (0.15 ind/ha) (Round and Gale 2008). This success can be associated to the scarcity of predators on Isla Victoria and the lack of other competing phasianid species as in its native range (Round and Gale 2008, Savini and Sukumal 2009, Sukumal and Savini 2009). Another striking aspect of the biology of the Silver Pheasant on Isla Victoria is that the composition of familiar groups has a polyandric structure (one female with more than one male). The study of groups on the native range showed that they have a polygynic structure (one male with more than one female; Johnsgard 1986, Savini and Sukumal 2009). The reasons for this difference are unknown, but one possible explanation is that there is an unbalanced proportion of sexes in the population (more males than females, probably owing to the absence of predators that selectively eliminate the more attractive males). If this species is capable of changing the structure of familiar groups as a consequence, this means that it have a high ecological flexibility, a specific trait that can be associated to invasibility (Sol et al. 2002).

Disturbance has long been cited as a factor that favours the colonization and invasion of non-native species (Elton 1958). For this reason, the association of non-native animals to areas with a high level of human disturbance (like conifer plantations) could be facilitating the invasion of natural areas by non-native animals in Patagonia (Lantschner et al. 2012). Both relative abundance indexes and population densities estimated in this work show that the Silver Pheasant is strongly associated to environments with a high level of disturbance, although it is abundant also in low disturbance areas.

On Isla Victoria the only native terrestrial bird species found today is the Chucao Tapaculo (*Scelorchilus rubecula*), which is strongly associated to areas with a low level of human disturbance (Martin-Albarracin et al. 2015b). In this and other studies, the Silver Pheasant has shown to have typically diurnal habits, as is usual in game birds (Johnsgard 1986). The Chucao Tapaculo also has diurnal habits, with peaks of activity at sunrise. The overlap in daily activity patterns (and likely in diet), as well as the aggressive behaviour of the Silver Pheasant observed in some videos, could promote a strong competition between these species.

The establishment of non-native carnivores, like American mink and feral domestic cat (detected through camera-trapping in this study), can be affecting terrestrial birds, both

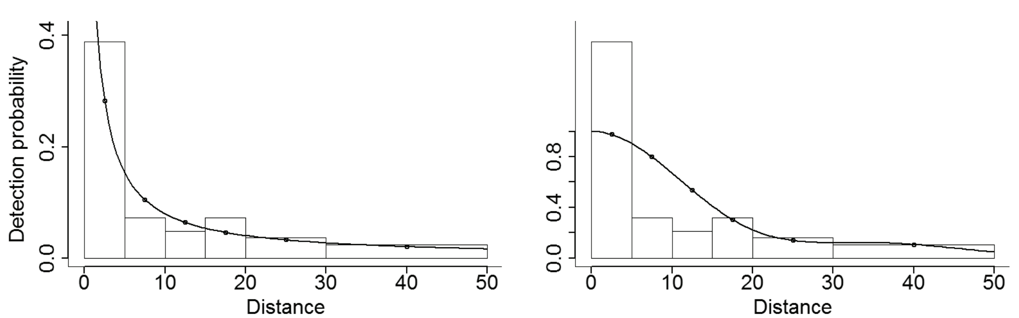

Figure 4. Plots of the detection function in distance sampling analysis of Silver Pheasant (*Lophura nycthemera*) in Isla Victoria (Nahuel Huapi National Park, Argentina) corresponding to the best models for each key function: Hazard-rate (left) and Half-normal, COS(2) (right). See table 2 for model fitting data.

native species and the Silver Pheasant. On this basis, we can hypothesize that both human disturbance and presence of non-native species can be affecting the abundance of the Chucao Tapaculo (Lantschner and Rusch 2007, Skewes et al. 2007). It is also possible that the Silver Pheasant has some impact on native species through disease transmission, as it happens with the Ring-necked Pheasant in non-native areas (Tompkins et al. 2000a, 2000b, 2001).

It has been suggested that some invasive species do not have negative impacts on native biodiversity and can even be beneficial by increasing local diversity (Thomas and Palmer 2015) or providing resources like habitat or food to native species (Davis et al. 2011). Some invasive species can also have a relevant role as seed dispersers of native plant species in their non-native distribution area (Chimera and Drake 2010). Given the high abundance of the Silver Pheasant in plantations it could be expected that it would consume large numbers of pine seeds at these locations. Pine invasions are an important problem in the region (Nuñez et al. 2011), and Nuñez et al. (2008) found that seed predation by local fauna was a main barrier for pine invasion on Isla Victoria. Camera records of Nuñez et al (2008) showed evidence that native birds and rodents consumed pine seeds and were acting as a barrier to pine invasion, but did not show evidence of pheasants consuming pine seeds. Therefore, it is unlikely that the Silver Pheasant is having the positive impact of pine invasion prevention. This species consume fleshy fruits and could be contributing to the dispersal of seeds of native plants. Notwithstanding, the emergence of novel interactions between non-native species (e.g., consumption of fleshy fruits of invasive shrubs by pheasants) could promote plant invasion. The role of the Silver Pheasant as a seed disperser, in particular, could be important for the ecosystem because it is a bird with a high body mass and thus probably with a higher dispersal capacity, by volume and distance, to that of native frugivorous birds. It can be especially important for the dispersal of seeds of plants whose fruits ripen during the winter, because it stays in the area all year round. On the island there are several native and non-native species of fleshy fruited plants that could benefit this way.

In summary, the Silver Pheasant successfully established on Isla Victoria, reaching higher abundances than those found at its native distribution area. It preferred habitats with a high degree of human disturbance; this factor probably facilitated its successful establishment. However, it also occupies areas of native forest with low disturbance levels. The high abundance of the Silver Pheasant, its large body size (in relation to native species) and its aggressive behaviour are characteristics than can influence its impact on native animal and plant communities.

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