New Forests (2022) 53:469–485
https://doi.org/10.1007/s11056-021-09867-w

Rehabilitation of *Nothofagus pumilio* forests in Chilean Patagonia: can fencing and planting season effectively protect against exotic European hare browsing?

Alejandro Huertas Herrera[1,2] · Álvaro Promis[3] · Mónica Toro-Manríquez[1,2] · María Vanessa Lencinas[4] · Guillermo Martínez Pastur[4] · Matías Río[5]

Received: 24 October 2020 / Accepted: 21 July 2021 / Published online: 27 July 2021

Abstract
In forests affected by heavy fires and continuous grazing of exotic herbivorous mammal species, *Nothofagus pumilio* (lenga) cannot recover naturally. The main factors that hinder the natural recovery of these forests and the feasibility of native tree plantations are the exotic herbivorous pressure, like that produced by *Lepus europaeus* (European hare), and the environment degradation degree by anthropic disturbances. The objective of this study was to evaluate different plantation efforts to recover *N. pumilio* forests degraded by fires in Chilean Patagonia. The plantation actions also included wire fences for sapling protection in 100 ha, where 60 ha were established during autumn (May 2012), and 40 ha were established during spring (October 2012). In March 2013 we recorded the height annual growth (cm year^{-1}), the section browsed at each sapling, the modification of plant form (number of new branches), and the vigor expression. We evaluated the data using one- and two-way ANOVAs, Cohen's *d* effect size, and chi-square analyses. We measured a total of 872 plants, where 42% presented damages caused by European hare browsing. These results indicated that the wire fences were not completely useful to stop the damage on saplings (Cohen's *d* effect size = <0.2). We also found that autumn plantations were more susceptible to damage than those established during spring. European hares predominantly browsed on a particular sapling section: the apical buds. As a consequence, the browsed saplings had lower height growth than undamaged ones. These outputs highlight the need to explore and implement alternative actions for the rehabilitation of these degraded deciduous forests, to achieve the objectives of sustainable management or to recover the natural ecosystem functions.

Keywords Native tree plantations · Saplings · Wire fences · Herbivory control · *Lepus europaeus* · Aysén Region

✉ Alejandro Huertas Herrera
alejandrohuertasherrera@ulterarius.com; alejandro.huertas@umag.cl

Extended author information available on the last page of the article

Introduction

The increasing transformation of natural habitats into agricultural and industrial lands has led to significant environmental changes worldwide (Watson et al. 2018). For example, in South America, human activities have transformed large areas of the Patagonian forests through intensive logging and conversion to grasslands, and in more subtle ways through the effects of biological invasions and heavy fires (Veblen 2007; Luque et al. 2011). In Chilean Patagonia, natural fires do not occur (except those associated with volcanic eruptions). However, over 3.5 million hectares of native forests were burned by settlers in the early twentieth century to promote the generation of pastures (Quintanilla 2008). These native forests are dominated by trees of the genus *Nothofagus* (Gajardo 1994), where deciduous *N. pumilio* (lenga) is one of the most widely distributed species across a wide range of latitudes (35° S to 56° S) and altitudes (from sea level to 2000 m a.s.l.) (Donoso 1993). Despite its genotypic and phenotypic plasticity (Premoli 2004), this species lacks enough regenerative strategies to cope with the adverse effect of fires or continuous browsing pressure (e.g. stump sprouting as the reproduction mechanism) (Kitzberger et al. 2002; Veblen et al. 2003).

Recurrent fires create extensive mineral soil areas and grasslands where the tree canopy is not closed, destined to extensive livestock grazing (Luque et al. 2011), and facilitating the spread of invasive species such as *Lepus europaeus* (European hare) (Jaksic et al. 2002; Bonino et al. 2010). This lagomorph inhabits open environments, intensifying the herbivorous pressure, and delaying or suppressing the natural regeneration of the natural forests (Ovalle et al. 2002; Reus et al. 2017). The European hare damages the trees, mainly during the establishment phase, browsing the apical buds and eventually the bark at its base, and therefore leading to individual mortality (Sullivan and Moses 1986; Urretavizcaya et al. 2018). The European hare damage is described as a potential cause of establishment failure in many native tree plantations across Patagonia, as it is considered responsible for retarding plant height growth and increasing desiccation, which leads to the plant's death (Jara 2013; Urretavizcaya et al. 2018).

In fire degraded areas, native tree plantations may offer a wide range of benefits that include the reduction of the probability of new fire events (Veblen et al. 2011), this is because grasslands and some shrublands are more combustible (Bowman et al. 2009; Veblen et al. 2011). Moreover, the recuperation of habitats is important for native biodiversity, soil stabilization, improvement of water provision, and landscape quality (McNamara et al. 2006; Toro Manríquez et al. 2019). Given that traumatic exogenous factors can compromise plant survival (Puntieri et al. 2006), areas with an abundant presence of exotic herbivores need control actions that prevent or mitigate predation, e.g. offering artificial protection during the early stages of plantations (Latorre et al. 2013). Direct or indirect control methods are useful in native tree plantations to counteract potential damages caused by problematic species (Salafsky et al. 2008). Direct control methods seek to eliminate individuals through poisoning, hunting, and trapping, while indirect methods are based on protecting plantations with perimeter fences, electric fences, individual plant shelters, and repellents (Löf et al. 2019). In this context, few experimental studies were done to evaluate the different methods and determine the effectiveness to achieve greater success in plantations with native species (Suding 2011). The first years of the planting are critical to the success of native tree plantation establishment, affecting mainly the individual plant survival (Sato 2000; Miller et al. 2006; Close et al. 2010). For this, climatic factors and planting season may have an important effect on plantation success (Sukhbaatar et al. 2020), where the quantification of the impact of introduced herbivores allows to improve guidelines for management and conservation. Besides, it is necessary to manage exotic species populations before any attempts to reintroduce native plants (Latorre et al. 2013; Stutz et al. 2017).

Currently, many activities (e.g. restoration and/or rehabilitation) for the recovery of degraded natural areas are considered one of the most effective strategies for climate change mitigation but it also highlights the urgent need for active actions (Clewell 2015; Bastin et al. 2019). Given the efforts put into this type of projects, the ecological expectations, and the economic resources invested, it is imperative to determine new management techniques that can successfully contribute to reduce the direct threats to the establishment of native tree plantations, such as herbivory control and/or the reduction of physical plant damage (Cernansky 2018). In this context, the aim was to assess native tree plantation efforts (e.g. the period of the planting along the year and the effectiveness of fencing for European hare exclusion) for the recovery of *N. pumilio* forests degraded by fires in the Chilean Patagonia. The following questions were addressed: (1) How do the European hare damages vary with control actions implemented during the plantation (e.g. wire fences, planting season)? (2) How do plants respond to the browsing damage (e.g. modification of plant growth, vigor)?

Materials and methods

Study area

The study was conducted in Lago Carlota National Reserve (~180 km^2) in the Northern Chilean Patagonia, Aysén Region (44° 27 ‘ S, 71° 44 ‘ W, 700 m a.s.l.; Fig. 1a), which was created in 1965. Before the creation of the reserve, many forest stands were burned for livestock grazing (CONAF 1998). Currently, livestock grazing is forbidden, and there were no signs of recent grazing within the study area. Most of the relief is plain or undulating lowlands (between 700 to ~1100 m a.s.l.), where only a few hill areas and mountain terrain display a rugged topography. The most common soil type is humic Andosol (FAO-UNESCO 1988). The regional climate is warm temperate meso-thermal, where the average temperature of the coldest months is 1.2 °C (winter), and the average of the warmest months is 19.0 °C (summer) (AGRIMED 2017). Annual precipitation includes snowfall and rarely exceeds 500 mm yr^{-1} (AGRIMED 2017), where February is the driest month (14 mm), and May, June, and July are the rainiest months (42 mm), with a snow depth of > 1 m during the winter season. The Carlota Lake (1.4 km^2) is the main water body and supplies several waterways and small streams that play an essential role in the hydrological regulation of the landscape. The vegetation hosts temperate *N. pumilio* and *N. antarctica* forests and also steppes. The mature forest stands cover approximately 70% of the land, which is mainly dominated by *N. pumilio* (including krummholz formations near the tree-line), from the lowland (700 m a.s.l.) to the mountains (1200 m a.s.l.). The *N. pumilio* forests are the most degraded forest type, where fires were set during the early twentieth century (around 900 ha were burned in the reserve). This National Reserve was selected because it contains a set of stands with a known history of fire and herbivory damage (where European hares are the main exotic herbivore), and comprises a typical burned forest landscape where native forests cannot naturally regenerate due to these trade-offs.

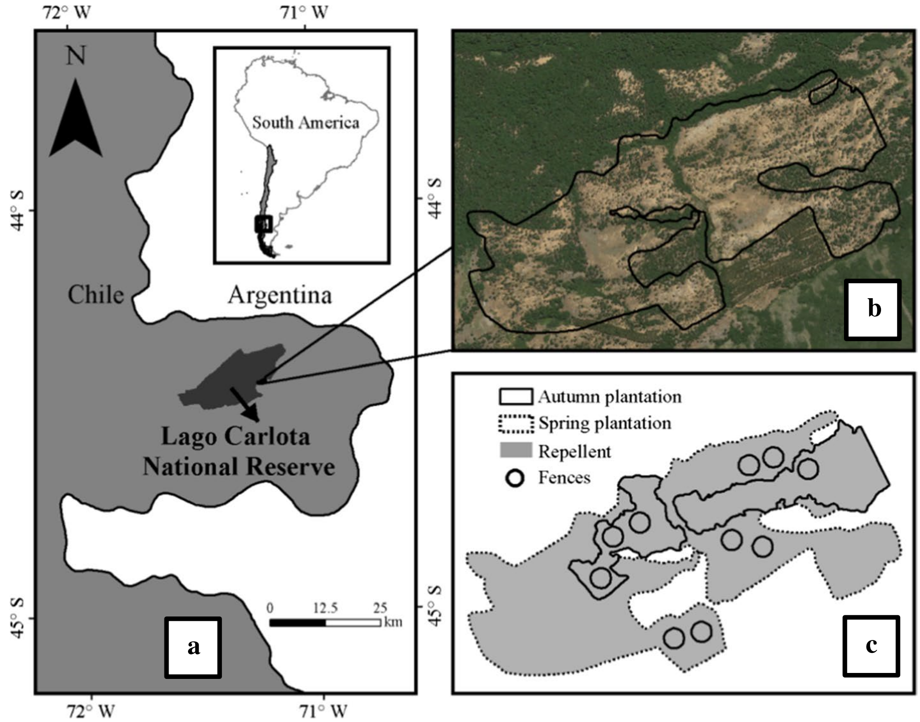

Fig. 1 Study area: **a** location of the Lago Carlota National Reserve (in dark grey); **b** *Nothofagus pumilio* degraded forest (black polygon) chosen for native tree plantations within the reserve (Bing image, Microsoft, USA); and **c** plantation establishment and the experimental treatments used for browsing damage control caused by European hares

Plantation establishment and experimental treatments

Approximately 100 ha of burned forests within the reserve were selected for the native tree plantation using aerial imagery from Bing (Microsoft, USA) and field visits (Fig. 1b). Naturally regenerated *N. pumilio* forests were only found in patches growing in flat areas (85%) and undulate areas (representing 15% with a ~ 4% of slope). The selected area for the plantation had < 30% of the original forest land-cover and a high density of European hares (approx. 5 individuals per ha). The average density was 60 trees ha^{-1} with dominant heights reaching 8 m, and perennial herbs and shrubs did not exceed 50 cm height in the understory. No significant erosive water processes were observed, such as sheet or gully erosion. More detailed information on the study area can be found in CONAF (1998) and Huertas Herrera (2014). Within the reserve, 100 ha were planted with *N. pumilio* saplings in 100 m^2 plots (with 20 saplings each) (Fig. 2), resulting in a density of 2,000 saplings ha^{-1}. The manual site preparation was carried out by local tree planters. The potential competing plants, as *Rumex acetosella*, *Anemone multifidia*, *Rytidosperma virescens*, and *Baccharis magellanica*, were manually removed within a quadrant of 30 × 30 cm around each plant. The saplings were planted on exposed soils. These saplings were 2–3 years-old, 3.8–4.5 mm (4.2 mean ± 1.4 standard deviation) in diameter at root collar (DRC) and 15–20 cm (15.1 mean ± 4.5 standard deviation) in height (H). The individuals presented

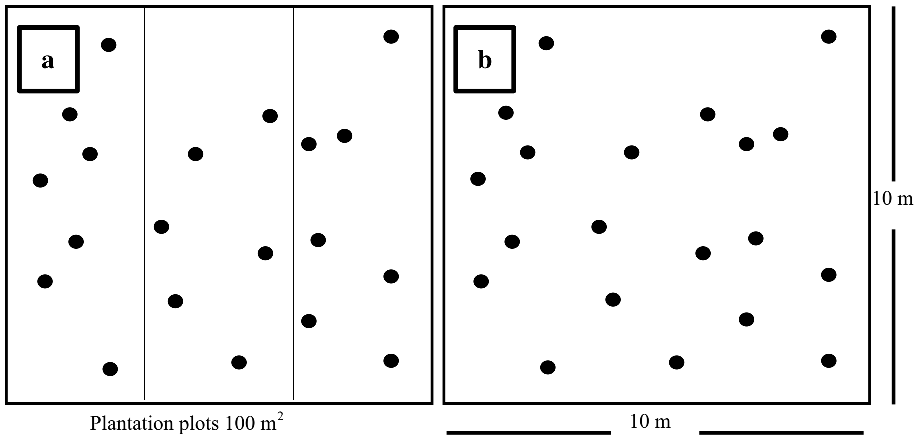

Fig. 2 The plot planting methodology was used. Black points represent *Nothofagus pumilio* saplings. **a** The vertical lines divide the surface area of 100 m^2 between segments (rectangles). Seven plants were placed in the outer rectangles, and six plants were placed in the center rectangle. **b** Linear representation of the plant distribution scheme at the time of planting

similar shapes (only one stem and erect stem) and a root/shoot mass ratio higher than 2:1. All plants were obtained from a forest nursery located 150 km away from the reserve, placed in a similar elevation range and aspect to ensure good adaptation to the environmental conditions. Planting was carried out during two seasons to assess the best planting period. The first was during May 2012 (autumn), when a total of 60 ha were planted, while the second was during October 2012 (spring), when a total of 40 ha were planted. All plants were treated with a hare-repellent substance (Pomarsol® Forte 80% WG Product Thiram of Bayer CropScience fungicide and repellent for lagomorphs) with Bond® sticker (200 L for approximately 52,000 plants). For their application, the repellents were hand-sprayed.

At the plantation site, several exclosures to protect saplings from European hare browsing were established (Fig. 1c). Ten exclosures of 1 ha consisted of fences circularly designed (1 m high and 355 m in perimeter) staked to the ground and constructed with a woven wire mesh (mesh size of 30 mm × 30 mm). Four exclosures were set up for the autumn plantation and six for the spring plantation. The status of wire fences was evaluated once in the summer of 2013, and all of them were found in perfect conditions. We did not register chewed holes in the fences or trees fallen over them. Besides, we did not find evidence of hares jumping fences. In this context, the treatments defined for this study consisted of T1, autumn unfenced plantation; T2, autumn fenced plantation; T3, spring unfenced plantation; and T4, spring fenced plantation.

Data collection

We collected data during summer 2013 for all the experimental treatments. We surveyed the survivorship and the browsing damage by European hares on saplings in 18 plots, representing 400 m^2 each (20 × 20 m). The plots were randomly distributed in each treatment at a distance of ~ 15 m from all remnant forests to avoid edge effects, with the following number of replicas (n): T1 (n = 4), T2 (n = 4), T3 (n = 4), and T4 (n = 6); ± 40 saplings were recorded at each 20 × 20 m plot. Within each plot, the annual growth in height (cm $year^{-1}$)

and the modification of plant form (e.g. number of new branches) were recorded. Also, the vigor was recorded, which was defined according to the visible expression of growth potential at each individual. These vigor expressions were classified as follows based on Torres (1998): (1) dead plant, when the sapling had primary leaves of brown coloring with no signs of vitality and had a fragile stem to the touch; (2) nearly dead plant, when the sapling had primary leaves of brown coloring, but with a sign of vitality as a recent regrowth; (3) wilting plant, when the sapling had primary leaves of brown-green or yellow coloring with few leaves and buds; (4) healthy plant, when the sapling had green leaves with active shoots; (5) very healthy plant, when the sapling had primary green leaves with evident growth and abundant foliage. The browsing occurrence (yes/no) and the section of the plant affected by browsing damage were distinguished as apical bud, stem branches, bark, and leaves. Based on the Browse Rating Index (BRI) proposed by Veblen et al. (1989), plant damage severity was estimated according to the proportion of above-ground biomass removed as follows: 0% (no damage), without signals of damage; 1–25% (low damage), when few above-ground biomass were removed; 25–50% (medium damage); 50–75% (high damage); > 75–90% (very high damage); and 90–100% (total cut-off), when cut and uneaten stems lied at the base of the plants.

Data analyses

The proportion of browsed saplings by European hares per plot was assessed using effect size as measured by Cohen's *d* effect size index, where differences between fenced and unfenced treatments (treatment mean browsing—control mean browsing) were calculated based on sample size and so-called pooled standard deviation in each planting period (autumn and spring). We used Cohen's *d* because the variances of the treatments were similar and because Cohen's *d* is recommended to estimate the effect size in large sample sizes (e.g. > 25 individuals) (Turner and Bernard 2006). Then, mean percentage values per plot of damage severity, classified by its category of damage (e.g. no damage, low damage, medium damage, high damage, very high damage, and total cut-off), were examined through two-way ANOVAs to evaluate the effects of damage severity classified by its category in the plant structure, with planting period (e.g. autumn and spring) and fencing use (e.g. unfenced and fenced) as main factors. The normality and homoscedasticity of the data were verified with the Shapiro–Wilk and Levene tests, respectively. When the parametric assumptions were not met, the data of damage severity were arcsine square root transformed to normalize their distribution and homoscedasticity, but non-transformed average data are shown. Additionally, one-way ANOVAs were conducted using the mean percentage of the annual increase of saplings with and without European hare browsing for testing the significant differences in each treatment (e.g. T1, T2, T3, and T4). We used post-hoc Tukey tests ($p < 0.05$) to separate significant mean values for all pairwise comparisons. All analyses were conducted using the Statgraphics Centurion XVI Version 16.1.11 (StatPoint Technologies, Warrenton, VA, USA) package.

Descriptive statistical analyses in terms of mean percentages and standard deviation (means ± SD) values were used to elucidate sapling survival (alive/dead) and their annual increments in height (cm year^{-1}) during the establishment of plantations. We calculated the mean percentage values per plot to compare damages according to plant sections (e.g. apical buds, stems, branches, bark, and leaves), and vigor (e.g. dead plants, nearly dead plants, wilting plants, healthy plants, and very healthy plants). Moreover, we compared the mean number of new branches (number per plant) in each treatment. The damage on the plant structure, the vigor, and the number of new branches were analyzed using Chi-square analysis to determine if treatments (e.g. T1, T2, T3, and T4) affected the proportion of sapling damage caused by browsing of European hares.

Results

Indirect control measures for browsing

A total of 872 saplings were measured, where 775 (89%) were alive and 509 (58%) did not present any signal of browsing. The Cohen's *d* index showed a very small effect size of the effectiveness of the fenced treatments in autumn (unfenced 0.46 ± 0.40, mean ± SD; fenced 0.55 ± 0.40, mean ± SD: Cohen's $d=0.18$) and spring (unfenced 0.24 ± 0.25, mean ± SD; fenced 0.25 ± 0.33, mean ± SD: Cohen's $d=0.03$) periods (Fig. 3). Besides, in the treatments established during autumn (unfenced and fenced) the saplings suffered more damage due to European hare browsing.

There were no interactions for the average percentage of browsed plants per category between the period and fencing factors ($p>0.05$), and fencing did not show significant differences between inside (fenced) and outside (unfenced) exclosures (Table 1). However, comparisons of the periods showed significant differences for autumn and spring in the categories without damage ($p<0.004$), medium damage ($p<0.001$), high damage ($p<0.009$), and very high damage ($p<0.018$). In autumn plantations, the herbivorous pressure was higher than in spring (from medium damage to a total cut-off), except for the low damage category.

Damage caused by European hares on saplings

Within the total number of the browsed saplings ($n=363$), apical buds were the plant structure with the highest proportion of browsing damage (73.7 ± 4%, mean ± SD), considering all the studied treatments (Fig. 4a). The unfenced spring treatment (T3) presented the smallest proportion of apical bud damages (67.4%). The branches showed a small proportion of browsing (9.1 ± 7%), followed by the stems (8.7 ± 7%), bark, and leaves, where all saplings presented a small percentage of damage (> 7%). During autumn (T1 and T2), the bark and leaves were either not browsed or represented less than 5% of the browsed sections, while during spring, these structures were

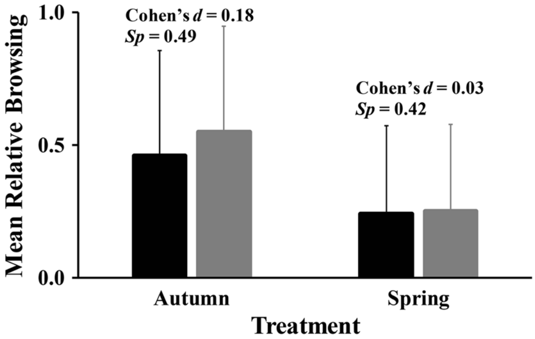

Fig. 3 Cohen's *d* effect sizes and pooled standard deviation (*Sp*) for saplings browsed by European hares (individuals per treatment) in the native tree plantation. Bars showed averages comparison (treatment mean browsing—control mean browsing) for the unfenced (black bars) and fenced (grey bars) treatments in each planting period (autumn and spring)

Table 1 Two-way ANOVAs and the average percentage value of plants for the factors of the period (autumn and spring) and fencing (unfenced and fenced) on the response variable plant damage severity

Factors	Type	No damage	Low damage	Medium damage	High damage	Very high damage	Total cut off
A: Period	Autumn	49.1 a	11.0	17.0 a	8.8 a	8.4 a	5.9
	Spring	70.0 b	18.3	4.9 b	2.8 b	2.0 b	1.9
	F	11.65	3.79	22.50	8.88	7.18	2.21
	(p)	*(0.004)*	*(0.072)*	*(<0.001)*	*(0.009)*	*(0.018)*	*(0.159)*
B: Fencing	Unfenced	61.4	16.3	10.4	4.9	4.1	2.9
	Fenced	57.1	13.1	11.5	6.6	6.2	4.9
	F	0.45	0.71	0.19	0.78	0.85	0.12
	(p)	*(0.513)*	*(0.412)*	*(0.666)*	*(0.393)*	*(0.372)*	*(0.372)*
A x B	F	0.577	0.00	0.19	1.85	0.44	1.56
	(p)	*(0.462)*	*(0.945)*	*(0.666)*	*(0.195)*	*(0.517)*	*(0.232)*

F, Fisher test; *(p)*, probability. Letters indicate differences using Tukey's test ($p < 0.05$). The text in italics is used to differentiate between the value of the statistical parameter (F and p) and other values. Medium damage, high damage, and very high damage were arcsine square root transformed to accomplish ANOVA assumptions, but the transformed data are not shown

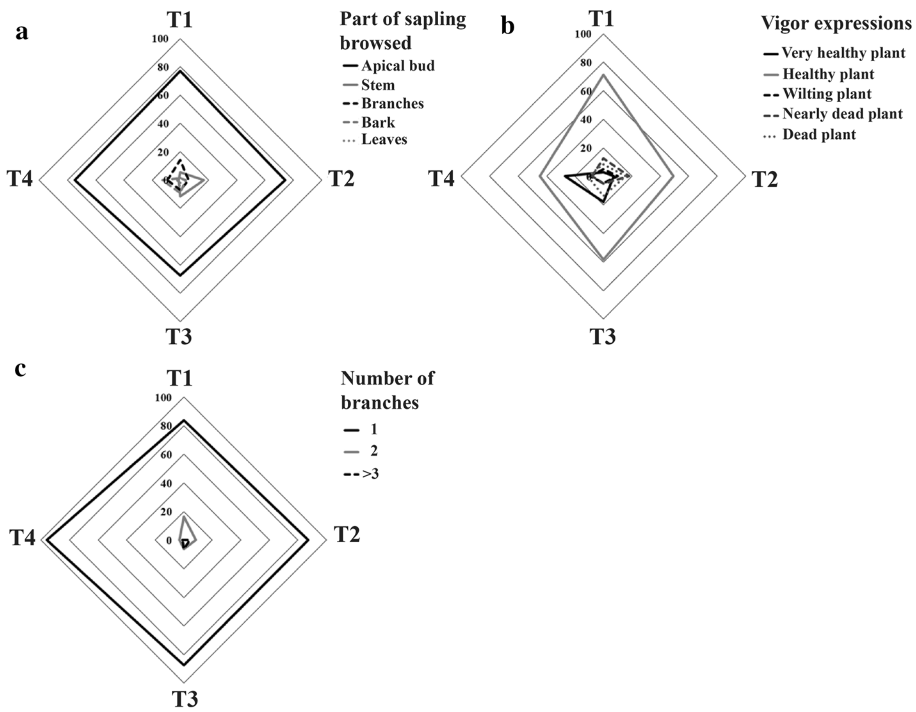

Fig. 4 Assessment of browsing damage caused by European hares, considering **a** the part of the sapling browsed, **b** the vigor expression, and **c** the number of branches (*n*). T1, autumn unfenced plantation; T2, autumn fenced plantation; T3, spring unfenced plantation; T4, spring fenced plantation. Numbers 0 to 100 in each subfigure refer to the percentage of saplings considered within the studied treatments

proportionately more affected. Remarkably, more than 50% of the plants were healthy (56 ± 12%) and 11 ± 11% were very healthy (Fig. 4b). Most of the very healthy plants were found in the spring treatments (T3 with 18% and T4 with 27%). The proportions of wilting (7 ± 3%), nearly dead (11 ± 6%), and dead (12 ± 3%) plants presented similar results, considering all the studied treatments. These vigor expressions were found especially in the autumn treatments, where only 13% and 18% of nearly dead plants were found in T1 and T2, respectively. On average, between 80 and 95% of the browsed plants of all treatments had new branches (Fig. 4c), and between 3 and 16% of the browsed plants had at least two new branches. Saplings with more than three branches represented less than 7%. For the analyses of new branches (Chi-square = 37.8; df = 12) and vigor expression (Chi-square = 113.8; df = 12), significant differences were found for all treatments ($p < 0.001$). The Chi-square test presented the same patterns that were described before, where autumn plantations were more susceptible to damage than those saplings planted during spring (see Appendix for details). Contrary to our expectations, significant differences in occurrence of new branches were not found between treatments (Chi-square = 113.8; df = 12; $p > 0.05$). On average, height growth increased in saplings without European hare browsing, varying from 3.6–3.7 cm yr^{-1} $plot^{-1}$ during autumn to 5.7–6.0 cm yr^{-1} $plot^{-1}$ during spring in the fencing treatments (Table 2). Most of the saplings without browsing have a major height growth compared to saplings damaged by European hare browsing, which were significant ($p < 0.05$) for T2 during

Table 2 One-way analyses of variance (ANOVAs) for annual increments (cm year^{-1}) of saplings with and without European hare browsing in the autumn and spring plantations. The number of plants and the mean percentage of the annual increase (values in parenthesis) were calculated within each treatment. T1, autumn unfenced plantation; T2, autumn fenced plantation; T3, spring unfenced plantation; T4, spring fenced plantation

Treatment		Not Browsed	Browsed	F *(p)*
Autumn	T1	171 (3.7)	145 (4.1)	1.24 (0.266)
	T2	68 (3.6) a	83 (2.2) b	8.32 (0.004)
Spring	T3	77 (5.7) a	13 (3.7) b	4.26 (0.042)
	T4	165 (6.0) a	58 (4.5) b	6.53 (0.011)
Overall		770 (4.5) a	560 (3.3) b	42.79 (< 0.001)

F*(p)* = Fisher test and significance in parentheses. Different letters for each row showed differences by the Tukey test at $p < 0.05$

autumn, as well as for the two spring treatments and the overall analysis (non-browsed with 4.5 cm yr^{-1} vs. browsed with 3.3 cm yr^{-1}).

Discussion

Effectiveness of indirect control methods

Throughout the study, the impact of European hares was negative for native tree plantation efforts in Lago Carlota Reserve, which included indirect methods of control to avoid browsing. These methods have been efficient in other plantation experiments, e.g. those reported by Löf et al. (2019) and Villalobos et al. (2019). The number of damaged plants in this research was similar to those reported in other experiments at similar latitudes. For example, according to Schlegel et al. (1979), plantations with *N. pumilio* considering different establishment techniques, as bare root planting and direct sowing in the box, presented higher plant mortality associated with the intense damage caused by European hares than in our study but also related to the extreme climatic local conditions (e.g. strong winds).

European hares have a territorial behavior and they recognize unfamiliar individuals that mark their area by cutting plants (Ovalle et al. 2002). This behavior may be favorable in areas with fences, as it might avoid possible transit of other wildlife (Poor et al. 2014; Reus et al. 2017), including other probable terrestrial predators (Gantchoff and Belant 2016; Frank and Eklund 2017). In this context, fences could be vital for European hares in cases where they have access within the fenced area and predators do not. Otherwise, fencing is usually more beneficial to predators concerning prey species. The absence of specific predators can generate an excessive increase in the population of the European hare, which can be directly related to a substantial impact on natural tree regeneration (Diamond 1986; Gantchoff and Belant 2016). Therefore, control over the browsing of European hares on saplings might require direct control methods instead of the simple implementation of indirect control methods. A previous study has established a link between wire fences and direct methods for more effective control of wild ungulate browsing (e.g. *Lama guanicoe*) over *N. pumilio* regeneration in southern Patagonia, where the use of barriers should be accompanied by a reduction in the density of undesired animals (Martínez Pastur et al. 2016).

The use of wire fences, implemented in native tree plantations, was not fully effective in preventing the damage over *N. pumilio* saplings caused by European hare browsing (e.g., Fig. 3, Cohen's $d = 0.18$ vs. 0.03). Fences are not always enough to prevent animal damage (Reidy et al. 2008), stopping or even slowing animal crossing (Wilkinson et al. 2021). Sometimes, one of the key factors that reduce effectiveness is that fences are not properly constructed (Honda 2018). However, although the fences of control implemented to avoid browsing and damage were not efficient, a key to achieving better results was found in terms of the planting time along the year (e.g. it was better at the beginning than at the end of the growing season). In temperate forests, an essential topic of native tree plantation efforts is the growth and plasticity of the plants during the planting period (Luoranen et al. 2018). For example, according to Sukhbaatar et al. (2020), in plantations of the Northern Hemisphere, the plant survival could be directly related to meteorological conditions during the planting period, because it may coincide with unfavorable environmental conditions such as prolonged drought or frequent windstorms.

Regarding the ecophysiological plasticity of the *Nothofagus* genus, in Patagonia, sapling planting is feasible before or after winter, so, individuals are not generally affected by ice damage before sprouting (Urretavizcaya et al. 2015, 2018). However, when saplings are planted during spring, they do not suffer during winter and may gain extra vigor, so, they are less likely to break after winter and can withstand mechanical or frost damage. Whereas in autumn, when saplings produce roots in the absence of leaves (as water requirements are lower and there are adequate temperatures for radical growth) and begin to grow when they have the appropriate environmental conditions (Martínez Pastur et al. 2011; Urretavizcaya et al. 2018). However, during autumn, saplings may not be adapted to harsh winter conditions. Thus, both season times (autumn and spring) have advantages and disadvantages for the native tree plantation efforts.

The biological requirements of the European hare might explain the higher damage during winter, since the food availability, such as grasses and herbs, is lower than in spring (Ovalle et al. 2002). In this context, autumn plantations could benefit European hares by offering an alternative supply of food. This is consistent with the diet preferences reported in European landscapes (Edwards et al. 2000). Therefore, we obtained a paradoxical effect in implementing wire fences, where they can protect the plants, but also can end up favoring the browsing of European hares by offering extra protection against predators, however, our research was conducted in the short-term (e.g. during the plantation establishment). While our findings on the seasonality of browse are important, they may be confounded by the fact that saplings planted earlier (autumn) had a longer time to be browsed than those planted during spring. However, understanding this fact helps to clarify the problem from the general point of view. When the wire fences were constructed, sometimes, it was not feasible to eliminate all of the individuals inside the plantations; however, the fences decreased the number of individuals in the rehabilitated areas. In light of this, the lack of difference can likely be due to: (1) the effectiveness of the fence to avoid European hares in the area, or (2) the effectiveness of the wire fences is only significant in the long-term. In addition, European hares can access the apical buds of larger plants when snow accumulation occurs, being critical between late autumn and early spring. However, deep winter snow (e.g. > 1 m) may also cover and protect smaller saplings. Earlier works have recognized that in environmental conditions without enough snow, winter is the season where the highest levels of browsing occur because of the evident decrease in the herbaceous stratum (Ovalle et al. 2002; Puig et al. 2017). Some studies in other temperate forests have shown that, during the regeneration establishment of native woodlands, plants are more browsed during winter and spring than during summer, particularly after planting (Rao et al. 2003).

In central Chile, physical protection methods have been evaluated to protect the regeneration of native plants by using wire fences, electric fences, shelters, or the application of repellents (Ovalle et al. 2002). In Patagonia, polycarbonate shelters and the facilitation by selecting special microsites have been used to improve sapling establishment (Valenzuela et al. 2016, 2018; Promis et al. 2018). However, whatever the method, the solution has been partially effective, or costly because replanting areas present low survival rates. In this context, many times, targeting the problem of rehabilitation of degraded forests in remote areas in terms of logistical work, e.g. monitoring of exotic species browsing, is limited, due to the difficult access during the entire year, in which there is not always professional supervision available, and because the labor can be done in a single season (usually during summer). In fact, in our study area, technicians could visit the plantations only once during the summer season. Therefore, positive or negative experiences are very important for future native tree plantation efforts, as is usually searched for adaptive learning in landscape management. We believe that the findings of this paper are quite representative of many rehabilitation efforts, and many times, money was spent on the same strategies that often fail due to the same reasons.

European hare browsing effects

Previous studies have suggested that damage to the apical buds does not necessarily result in the death of the plant, but often produces undesirable ramifications (Till-Bottraud et al. 2012) with a significant loss of the aerial biomass (Rao et al. 2003). However, if browsing occurs near the base, the plants could die because of the excessive damage (Ovalle et al. 2002). According to previous studies (e.g. Urretavizcaya et al. 2015), the height that plants must exceed to enter the safe zone to escape death and/or deformation caused by loss of apical buds by hares is near 60 cm. Considering *N. pumilio* can reach 1 m height in 5–10 years (Schmidt et al. 2003), this does not prevent individuals from being attacked by hares in the future, e.g. however it does prevent the browsing of the apex (which deforms plants) and guarantees the survival of the individuals (Jara 2013; Urretavizcaya et al. 2015).

The vigor of the plants was optimal in the studied saplings probably because the environmental factors were not so hard during the study period (Urretavizcaya et al. 2015; Luoranen et al. 2018). However, many herbivores prefer to feed on vigorous plants as they are more nutritious and palatable (Bergquist et al. 2003; Pardo and Pulido 2017). As was observed for other herbivore species (Price 1991), European hares browsed preferentially on vigorous plants (Edwards et al. 2000; Puig et al. 2017). Therefore, it would be beneficial that individuals of *N. pumilio* quickly overcome 60 cm height to prevent death from browsing, or to avoid becoming deformed. Furthermore, microclimatic characteristics exert intense selective pressure on the first stages of development of the *Nothofagus* genus (Alberdi 1987; Martínez Pastur et al. 2011; Urretavizcaya et al. 2015), in addition to other physiological properties related to watering balance and resistance to environmental factors (Toro Manríquez et al. 2019). For example, neighboring vegetation (nurse plants), as *Berberis microphylla* in South Patagonia (Bustamante et al. 2020) can increase the probability that palatable plants persist despite high herbivore pressure (Miller et al. 2006; Stutz et al. 2015, 2017; Löf et al. 2019).

Concluding remarks

Here, the use of wire fences implemented to protect native tree plantations was not fully effective in preventing the browsing of European hares and the subsequent damage over saplings of *N. pumilio* in the Lago Carlota National Reserve (Chile), and no significant differences were found in the damage of the plants outside fencings. Findings on the effects of the season showed that autumn plantations were more at risk for hare browsing than spring plantations. This highlights the importance of considering the plantation season in future studies, analyzing European hare browsing damage effects to face projects focusing on reversing the historical forest trends of degradation through native tree plantation programs. In addition, empirical evidence showed that this damage to the individuals of *N. pumilio* caused changes in their growth through the formation of new branches that compete for apical buds, affecting the desirable form of plants (e.g. deforming them). Our study showed that European hare browsing poses one of the most significant challenges to the early success of plantations with *N. pumilio* trees. The rehabilitation of forests in Chilean Patagonia, in general, seems to be problematic by establishing native saplings and implementing interventions targeted at controlling the damage caused by herbivores, which further affects the structure and survival of plants.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11056-021-09867-w.

Acknowledgements The authors are grateful to the entire team of the Sociedad Agrícola y Forestal SNP and Fundación Reforestemos Patagonia for funding this research and the support provided in the field. Thanks also to C. Jara and F. Soto for their help in the field, and to the Lago Carlota National Reserve. Thanks to Luis Cárcamo Oyarzún, Academic Writing Center, Universidad de Magallanes.

References

AGRIMED (2017) Atlas Agroclimático de Chile: Estado Actual y Tendencias del Clima, Tomo VI Regiones de Aysén y Magallanes. Santiago, Chile

Alberdi M (1987) Ecofisiología de especies chilenas del género Nothofagus. Bosque 8:77–84. https://doi.org/10.4206/bosque.1987.v8n2-02

Bastin J-F, Finegold Y, Garcia C, Mollicone D, Rezende M, Routh D, Zohner CM, Crowther TW (2019) The global tree restoration potential. Science 365:76–79. https://doi.org/10.1126/science.aax0848

Bergquist J, Örlander G, Nilsson U (2003) Interactions among forestry regeneration treatments, plant vigour and browsing damage by deer. New for 25:25–40. https://doi.org/10.1023/A:1022378908827

Bonino N, Cossíos D, Menegheti J (2010) Dispersal of the European hare, *Lepus europaeus* in South America. Folia Zoologica. 59:9–15. https://doi.org/10.25225/fozo.v59.i1.a3.2010

Bowman DM, Balch JK, Artaxo P, Bond WJ, Carlson JM, Cochrane MA, D'Antonio CM, DeFries RS, Doyle JC, Harrison SP (2009) Fire in the earth system. Science 324:481–484. https://doi.org/10.1126/science.1163886

Bustamante GM, Soler R, Blazina AP, Arena ME (2020) Fruit provision from *Berberismicrophylla* shrubs as ecosystem service in *Nothofagus* forest of Tierra del Fuego. Heliyon 6:e05206. https://doi.org/10.1016/j.heliyon.2020.e05206

Cernansky R (2018) How to plant a trillion trees. Nat 560:542–545. https://doi.org/10.1038/d41586-018-06031-x

Clewell AF (2015) Ecological restoration principles relative to *Nothofaguspumilio* (Poepp. & Endl.) Krasser (Nothofagaceae) forest restoration. Ann Inst Patagon 43:123–126. https://doi.org/10.4067/S0718-686X2015000100010

Close D, Paterson S, Corkrey R, McArthur C (2010) Influences of seedling size, container type and mammal browsing on the establishment of *Eucalyptus globulus* in plantation forestry. New for 39:105. https://doi.org/10.1007/s11056-009-9158-3

CONAF (1998) Plan de Manejo Reserva Forestal Lago Carlota. Documento de Trabajo Nº 281. Ministerio de Agricultura, Corporación Nacional Forestal, Gerencia de Operaciones, Unidad de Gestión Patrimonio Silvestre, XI Región de Aysén. Coyhaique, Chile

Diamond J, Case T (1986) Overview: Introductions, extinctions, exterminations, and invasions. In: Diamond J, Case T (eds) Community ecology. Harper and Row, Nueva York, pp 65–79

Donoso C (1993). Bosques templados de Chile y Argentina: Variación, estructura y dinámica. Ed. Universitaria. Santiago, Chile

Edwards PJ, Fletcher MR, Berny P (2000) Review of the factors affecting the decline of the European brown hare, *Lepus europaeus* (Pallas, 1778) and the use of wildlife incident data to evaluate the significance of paraquat. Agric Ecosyst Environ 79:95–103. https://doi.org/10.1016/S0167-8809(99)00153-X

FAO-UNESCO (1988) Soil Map of the World, Revised Legend. FAO, Rome, Italy

Frank J, Eklund A (2017) Poor construction, not time, takes its toll on subsidised fences designed to deter large carnivores. PLoS ONE 12:e0175211. https://doi.org/10.1371/journal.pone.0175211

Gajardo R (1994) La vegetación Natural de Chile: Clasificación y distribución geográfica. Ed. Universitaria. Santiago, Chile

Gantchoff MG, Belant JL (2016) Patterns of coexistence between two mesocarnivores in northern Patagonia in the presence of invasive hares and anthropogenic disturbance. Austral Ecol 41:97–105. https://doi.org/10.1111/aec.12303

Honda T (2018) A technique for preventing wildlife intrusion via the intersection between drainage ditches and fences: deer, macaque, raccoon dog, fox, and badger damage management. Crop Prot 113:29–32. https://doi.org/10.1016/j.cropro.2018.07.012

Huertas Herrera A (2014) Evaluación de acción de conservación para la recuperación de bosques de *Nothofagus pumilo* (Poepp. et Endl.) Krasser degradados por incendios históricos en la Reserva Nacional Lago Carlota, Región de Aysén. Master thesis, Universidad de Chile. Santiago, Chile

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

Jara C (2013). Evaluación del crecimiento y del daño por herbivoría en una plantación inicial de *Nothofagus antarctica* (G. Forst.) Oerst. Y *Nothofagus betuloides* (Mirb) Oerst en la provincia de Palena, X región. B.Sc. Thesis. Universidad de Chile. Santiago, Chile. 54 p

Kitzberger T, Raffaele E, Veblen TT (2002) Variable community responses to herbivory in fire-altered landscapes of northern Patagonia, Argentina. Afr J Range Forage Sci 22:85–91. https://doi.org/10.2989/10220110509485865

Latorre L, Larrinaga A, Santamaría L (2013) Combined impact of multiple exotic herbivores on different life stages of an endangered plant endemism, *Medicagocitrina*. J Ecol 101:107–117. https://doi.org/10.1111/1365-2745.12005

Löf M, Madsen P, Metslaid M, Witzell J, Jacobs DF (2019) Restoring forests: regeneration and ecosystem function for the future. New for 50:139–151. https://doi.org/10.1007/s11056-019-09713-0

Luoranen J, Saksa T, Lappi J (2018) Seedling, planting site and weather factors affecting the success of autumn plantings in Norway spruce and Scots pine seedlings. For Ecol Manag 419:79–90. https://doi.org/10.1016/j.foreco.2018.03.040

Luque S, MartínezPastur G, Echeverría C, Pacha MJ (2011) Overview of biodiversity loss in South America, a landscape perspective for sustainable forest management and conservation in temperate forests. In: Li C, Lafortezza R, Chen J (eds) Landscape ecology and forest management: challenges and solutions in a changing globe. Springer, Amsterdam

MartínezPastur G, Soler R, Ivancich H, Lencinas MV, Bahamonde H, Peri PL (2016) Effectiveness of fencing and hunting to control *Lama guanicoe* browsing damage, Implications for *Nothofaguspumilio* regeneration in harvested forests. J Environ Manag 168:165–174. https://doi.org/10.1016/j.jenvman.2015.11.051

Martínez Pastur GJ, Lencinas MV, Soler RM, Ivancich HS, Peri PL, Moretto AS, Hernández LF, Lindström I (2011) Plasticidad ecofisiológica de plántulas de *Nothofagus pumilio* frente a combinaciones de niveles de luz y humedad en el suelo. Ecol Austral 21:301–315.

McNamara S, Tinh V, Erskine P (2006) Rehabilitating degraded forest land in central Vietnam with mixed native species plantings. For Ecol Manag 233:358–365. https://doi.org/10.1016/j.foreco.2006.05.033

Miller AM, McArthur C, Smethurst PJ (2006) Characteristics of tree seedlings and neighbouring vegetation have an additive influence on browsing by generalist herbivores. For Ecol Manag 228:197–205. https://doi.org/10.1016/j.foreco.2006.03.003

Ovalle C, Ojeda F, Skewes O (2002) Evaluación de distintos métodos de prevención de daño causado por lagomorfos en plantaciones de tagasaste (*Chamaecytisusproliferus* spp. palmensis). Agric Téc 62:396–405. https://doi.org/10.4067/S0365-28072002000300005

Pardo A, Pulido F (2017) Upscaling hypotheses on herbivore damage in plants facing environmental stress, Variation among scales and plant enemies in a relict tree. Basic App Ecol 21:34–44. https://doi.org/10.1016/j.baae.2017.07.002

Poor EE, Jakes A, Loucks C, Suitor M (2014) Modeling fence location and density at a regional scale for use in wildlife management. PLoS ONE 9:e83912. https://doi.org/10.1371/journal.pone.0083912

Premoli A (2004) Variación en *Nothofagus pumilio* (Poepp. et Endl.) Krasser (lenga). In: Donoso C, Premoli A, Gallo LE, Ipinza R (eds). Variación Intraespecífica en las especies arbóreas de los bosques templados de Chile y Argentina. Editorial Universitaria. Santiago, Chile. pp 145–166

Price PW (1991) The plant vigor hypothesis and herbivore attack. Oikos. https://doi.org/10.2307/3545270

Promis A, Cruz G, Galindo N, Olivares S (2018) Respuesta inicial de actividades silviculturales para recuperar bosques degradados de ñirre (*Nothofagus antarctica* (G. Forst.) Oerst.) en la Norpatagonia chilena. Facultad de Ciencias Forestales y de la Conservación de la Naturaleza, Universidad de Chile. Santiago, Chile

Puig S, Rosi MI, Videla F, Mendez E (2017) Flexibility in the food selection by the European hare (*Lepus europaeus*) along the altitudinal gradient of the Southern Andean Precordillera (Argentina). Mamm Res 62:75–87. https://doi.org/10.1007/s13364-016-0288-7

Puntieri JG, Stecconi M, Brion C, Mazzini C, Grosfeld J (2006) Effects of artificial damage on the branching pattern of *Nothofagusdombeyi* (Nothofagaceae). Ann for Sci 63:101–110. https://doi.org/10.1051/forest:2005102

Quintanilla V (2008) Perturbaciones a la vegetación nativa por grandes fuegos de 50 años atrás, en bosques Nordpatagónicos. Caso de estudio en Chile Meridional. Anales de Geografía 28:85–104. https://revistas.ucm.es/index.php/AGUC/article/view/AGUC0808110085A

Rao S, Iason G, Hulbert I, Elston D, Racey PA (2003) The effect of sapling density, heather height and season on browsing by mountain hares on birch. J App Ecol 40:626–638. https://doi.org/10.1046/j.1365-2664.2003.00838.x

Reidy MM, Campbell TA, Hewitt DG (2008) Evaluation of electric fencing to inhibit feral pig movements. J Wildl Manag 72:1012–1018. https://doi.org/10.2193/2007-158

Reus ML, de los Ríos C, Peco B, Giannoni SM, Campos CM (2017) Trophic interactions among native and exotic herbivorous mammals in the Ischigualasto Provincial Park (San Juan, Argentina). Ecol Austral. 27:392–403. https://doi.org/10.25260/EA.17.27.3.0.545

Salafsky N, Salzer D, Stattersfield AJ, Hilton-Taylor C, Neugarten R, Butchart SHM, Collen B, Cox N, Master LL, O'connor S, Wilkie D (2008) A standard Lexicon for biodiversity conservation, unified classifications of threats and actions. Conserv Biol 22:897–911. https://doi.org/10.1111/j.1523-1739.2008.00937.x

Sato T (2000) Effects of rodents gnawing on the survival of current-year seedlings of *Quercuscrispula*. Ecol Res 15:335–344. https://doi.org/10.1046/j.1440-1703.2000.00352.x

Schlegel F, Veblen TT, Escobar B (1979) Estudio ecológico de la estructura, composición, semillación y regeneración del bosque de lenga (*Nothofagus pumilio*) XI Región. Informe de Convenio N° 8 Proyectos Serplac con CONAF XI Región - Universidad Austral de Chile. Valdivia, Chile

Schmidt H, Cruz G, Promis A, Álvarez M (2003) Transformación de los bosques de lenga vírgenes e intervenidos a bosques manejados (Guía para los bosques demostrativos). Universidad de Chile, Facultad de Ciencias Forestales, Publicaciones Misceláneas Forestales Nº 4. 60 p.

Stutz RS, Banks PB, Dexter N, McArthur C (2015) Herbivore search behaviour drives associational plant refuge. Acta Oecol 67:1–7. https://doi.org/10.1016/j.actao.2015.05.004

Stutz RS, Croak BM, Leimar O, Bergvall UA (2017) Borrowed plant defences: deterring browsers using a forestry by-product. For Ecol Manag 390:1–7. https://doi.org/10.1016/j.foreco.2017.01.013

Suding KN (2011) Toward an era of restoration in ecology: successes, failures, and opportunities ahead. Ann Rev Ecolo Evol Syst 42:465–487. https://doi.org/10.1146/annurev-ecolsys-102710-145115

Sukhbaatar G, Ganbaatar B, Jamsran T, Purevragchaa B, Nachin B, Gradel A (2020) Assessment of early survival and growth of planted Scots pine (*Pinussylvestris*) seedlings under extreme continental climate conditions of northern Mongolia. J for Res 31:13–26. https://doi.org/10.1007/s11676-019-00935-8

Sullivan TP, Moses RA (1986) Demographic and feeding responses of a snowshoe hare population to habitat alteration. J Appl Ecol 23:53–63. https://doi.org/10.2307/2403080

Till-Bottraud I, Fajardo A, Rioux D (2012) Multi-stemmed trees of *Nothofaguspumilio* second-growth forest in Patagonia are formed by highly related individuals. Ann Bot 110:905–913. https://doi.org/10.1093/aob/mcs146

Toro Manríquez M, Cellini JM, Lencinas MV, Peña KA, MartínezPastur G (2019) Suitable conditions for natural regeneration in variable retention harvesting of southern Patagonian *Nothofaguspumilio* forests. Ecol Proc 8:18. https://doi.org/10.1186/s13717-019-0175-7

Torres J (1998) Patología Forestal: Principales enfermedades de nuestras especies forestales. 2° Edición. Mundi-prensa libros. Madrid, España

Turner HM, Bernard RM (2006) Calculating and synthesizing effect sizes. Contemp Issues Commun Sci Disord 33:42–55. https://doi.org/10.1044/cicsd_33_S_42

Urretavizcaya MF, Peri PL, Monelos L, Arriola H, Oyharçabal MF, Contardi L, Muñoz M, Sepúlveda R, Defosse G (2018) Soil and vegetation conditions in three burned *Nothofaguspumilio* forests in Argentina and experiences for their active restoration. Ecol Austral. 28:383–399. https://doi.org/10.25260/EA.18.28.2.0.480

Urretavizcaya MF, Pastorino MJ, Mondino V, Contardi LT (2015) La Plantación con Árboles Nativos. In: Chauchard L, Frugoni MC, Nowak C (eds). Manual de Buenas Prácticas Forestales en el Noroeste de Patagonia. Buenos Aires, Argentina. pp 335–368

Valenzuela P, Arellano EC, Burger JA, Becerra P (2016) Using facilitation microsites as a restoration tool for conversion of degraded grasslands to *Nothofagus* forests in Southern Patagonia. Ecol Eng 95:580–587. https://doi.org/10.1016/j.ecoleng.2016.06.116

Valenzuela P, Arellano EC, Burger J, Oliet JA, Pérez MF (2018) Soil conditions and sheltering techniques improve active restoration of degraded *Nothofaguspumilio* forests in Southern Patagonia. For Ecol Manag 424:28–38. https://doi.org/10.1016/j.foreco.2018.04.042

Veblen TT (2007) Temperate forests of the southern Andean region. In: Veblen TT, Orme A, Young K (eds) Physical geography of South America. Oxford University Press, London, pp 217–231

Veblen TT, Mermoz M, Martin C, Ramilo E (1989) Effects of exotic deer on forest regeneration and composition in Northern Patagonia. J App Ecol 26:711–724. https://doi.org/10.2307/2404095

Veblen TT, Kitzberger T, Raffaele E, Lorenz DC (2003) Fire history and vegetation changes in Northern Patagonia, Argentina. In: Veblen TT, Baker WL, Montenegro G, Swetnam TW (eds) Fire and climatic change in temperate ecosystems of the Western Americas. Ecological Studies (Analysis and Synthesis), Springer. New York

Veblen TT, Holz A, Paritsis J, Raffaele E, Kitzberger T, Blackhall M (2011) Adapting to global environmental change in Patagonia: what role for disturbance ecology? Austral Ecol 36:891–903. https://doi.org/10.1111/j.1442-9993.2010.02236.x

Villalobos A, Olsson G, Birkedal M, Löf M (2019) The effects of four repellents on bank vole consumption and germination of beech nuts and acorns. New for 50:241–254. https://doi.org/10.1007/s11056-018-9660-6

Watson JEM, Evans T, Venter O, Williams B, Tulloch A, Stewart C et al (2018) The exceptional value of intact forest ecosystems. Nat Ecol Evol 2:599–610. https://doi.org/10.1038/s41559-018-0490-x

Wilkinson CE, McInturff A, Kelly M, Brashares JS (2021) Quantifying wildlife responses to conservation fencing in East Africa. Biol Conserv 256:109071. https://doi.org/10.1016/j.biocon.2021.109071

Authors and Affiliations

Alejandro Huertas Herrera[1,2] · Álvaro Promis[3] · Mónica Toro-Manríquez[1,2] · María Vanessa Lencinas[4] · Guillermo Martínez Pastur[4] · Matías Río[5]

[1] Ulterarius Consultores Ambientales y Científicos Ltda, Río de Los Ciervos 5862, Loteo D, km 6 ½ Sur, Punta Arenas, Chile

[2] Departamento de Ciencias Agropecuarias y Acuícolas, Universidad de Magallanes (UMAG), Avenida Bulnes 01855, 6210427 Punta Arenas, Magallanes, Chile

[3] Facultad de Ciencias Forestales y de la Conservación de la Naturaleza, Departamento de Silvicultura y Conservación de la Naturaleza, Universidad de Chile, Av. Santa Rosa 11315, 9206 La Pintana, Santiago, Chile

[4] Laboratorio de Recursos Agroforestales, Centro Austral de Investigaciones Científicas (CADIC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Houssay 200, 9410 Ushuaia, Tierra del Fuego, Argentina

[5] Fundación Reforestemos Patagonia, Del Inca, 4622 Las Condes, Santiago, Chile