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Modification of the flora composition in edges of fragmented *Austrocedrus chilensis* forests in Patagonia

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Abstract

In the Patagonian Andes of Argentina, *Austrocedrus chilensis* is one of the native tree species most affected by forest fragmentation, resulting in remnants stands surrounded by grasslands. We studied vegetation in the edges of stands of dense *A. chilensis* adjoining areas that were cut 10 years earlier, with special reference to *A. chilensis* regeneration, diversity, abundance and specific species distribution. We found that the original composition of the vegetation had been strongly modified, there was a high proportion of exotic herbaceous species in the edge. Diversity and abundance of woody species was superior in the core forest ($p = 0.0289$ and $p = 0.0149$), and so was the richness of native species ($p = 0.0053$) and regeneration of *A. chilensis* ($p = 0.0408$). On the other hand the abundance of herbaceous species was greater in the edge ($p = 0.0197$). During the first years of the succession, the forest in the edge area tends to retract.

Key words: Edge effect, human influence, specific richness, tree regeneration, vegetation gradients.

Resumen

Modificación de la composición de la flora en bordes de bosques fragmentados de *Austrocedrus chilensis* en Patagonia

Austrocedrus chilensis es una de las especies arbóreas nativas del bosque andino patagónico más afectadas por el proceso de fragmentación, originando bosquetes remanentes rodeados de pasturas. Estudiamos la vegetación en bordes de *A. chilensis* adyacentes a áreas cortadas 10 años atrás, con especial referencia a la regeneración de *A. chilensis,* diversidad, abundancia y distribución especifica. Se encontró que la composición original de la vegetación fue fuertemente modificada, con una alta proporción de especies herbáceas exóticas en la zona de borde. La diversidad y la abundancia de especies leñosas fueron mayores en el interior del bosque ($p = 0.0289$ y $p = 0.0149$), lo mismo que la riqueza de especies nativas ($p = 0.0053$) y la regeneración de *A. chilensis* ($p = 0.0408$), en tanto que la abundancia de especies herbáceas fue mayor en el borde ($p = 0.0197$). Durante los primeros 10 años de la sucesión posterior al disturbio, la tendencia de los bosquetes de *A. chilensis* remanentes es la retracción.

Palabras clave: Efecto de borde, influencia antrópica, riqueza específica, regeneración, gradiente de vegetación.

Introduction

Habitat loss and fragmentation are closely related processes. A conceptual perspective developed by Haila (2002) suggests that fragmentation must be regarded as a specific form of habitat degradation. One of the most important consequences of forest fragmentation is the increase of edge areas. In the edges there are microclimatic gradients that can affect seed dispersal, pollination and prevent the expansion of the patch (Aizen and Feinsinger, 1994; Kapos *et al.,* 1997). The edge is an area of contact between two adjacent ecosystems, that influence each other, creating special conditions which differ from the original ones (Murcia,

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1995). Fox *et al.* (1996) working in rainforest remnants partially disturbed, found that the composition of the remnants differed from that in the edges. There was a decrease of the rainforest plants, a peak of colonising plants in the edges and weeds outside the forest. For conservation purposes the size of the patch and the modification of the forest features beyond their range of natural intrinsic variation owed to the exposure to the edge are key factors in predicting if forest remnants will decrease or increase (Esseen, 1994; Young and Mitchell, 1994; Murcia, 1995).

A. chilensis (D. Don) Pic. Ser. *et* Bizzarri is an endemic specie of the cold temperate forests in Argentina and Chile. It is a Cupressaceae reaching 20-25 m in height, with pyramidal shape, and small, persistent leaves (Dimitri *et al.* 1997). It is a dioecious specie, with greater proportion of male trees (Brion *et al.* 1993). It reproduces by seeds with anemophilous dispersion (Grosfeld and Barthelemy 2004). Currently pure *A. chilensis* forests and mixed *A. chilensis* -*Nothofagus* spp. areas cover 135,400 hectares (Bran *et al.,* 2002).

Austrocedrus chilensis forests are located in places of favorable microclimatic characteristics (Fulco, 1995). In these places the specie has been historically affected by unplanned development of human settlements. This has increased risk of fires (Rothkugel, 1916; Veblen and Lorenz, 1987; Bondel and De Almeida, 1996), and has promoted irrational use of the forest for cattle grazing (Seibert, 1982), substitution by exotic conifer species (Loguercio *et al.,* 1999) and timber exploitation, currently restricted to stands with weakened or dead trees affected by a disease named 'mal del ciprés' (Dirección General de Bosques y Parques de Chubut, 1999).

Our previous research revealed a reduction of the area covered by *A. chilensis* (Carabelli *et al.,* 2003; Carabelli, 2004). Now we are studying changes in the composition of the vegetation. Regeneration of *A. chilensis* requires shrub covering during its first development stages (Gobbi, 1994; Veblen *et al.,* 1995), so modifications in the structure of the forest could have important effects on the regeneration. Thus, we are especially interested in determining if *A. chilensis* regeneration take place in edge sectors, to infer about the possible decrease or increase of the remnant size in time. In this paper we study changes in the diversity and abundance of the flora and the *A. chilensis* regeneration in forest edges. Additional studies that are in progress in the same area include remnant size and shape and the influence of different environmental surroundings.

Methods

These issues were studied in the northwestern area of Chubut Province, which is located in the center of Patagonia (figure 1). Three sites were selected in a 2001 SPOT satellite image. Their edges had been formed 10 years earlier due to a clear cut. Over there stands of *A. chilensis* surrounded by grassland developed. The three selected sites had similar shapes and dimensions, and were separated by a distance of at least 500 m. In forest remnants, the canopy consists mainly of *A. chilensis,* and the undercanopy consists of shrubs, woody creepers and sparse herbaceous plants.

Data collection

At each site, two 100 m long transects were located perpendicularly to the edge: 70 m of the transect run into the forest and 30 m run into the grass land. Each one was divided in 10 plots of 100 m^2, each of them was considered a different treatment *(e. g.* 10 m of the edge, 20 m, 30 m, etc.).

In each plot all vascular plants species were identified and quantified. The herbaceous species cover percentage was measured in four circular 0.5 m^2 subplots randomly placed. Shrubs and creepers were individually counted in quadrants of 25 m^2, also randomly selected in each plot. Those individuals with diameter at breast height (DBH) higher than 5 cm were considered trees and they were counted in each 100 m^2 plot. Regeneration of *A. chilensis* was measured according to their height: those smaller than 10 cm were directly counted in the subplots for herbaceous species, and the ones taller than 10 cm were counted in the quadrants for shrubs.

Data analysis

It was assumed that the three edges constituted three repetitions. In each edge two transects were settled. During the analysis process the data from both transects was averaged.

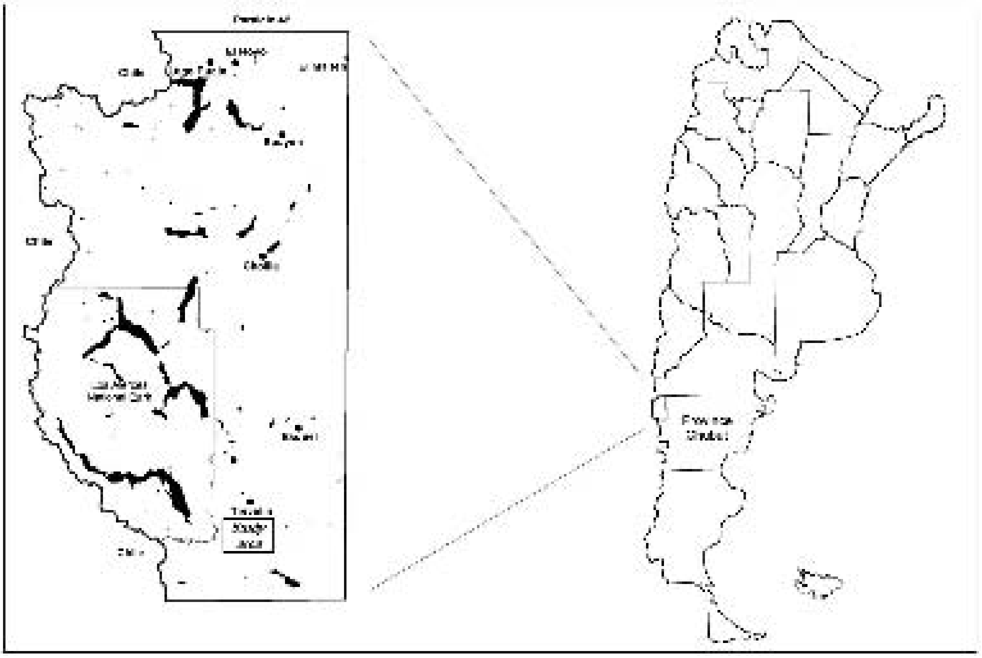

Figure 1. Study area in Province Chubut.

We tested the following variables: diversity; distribution of native, exotic, woody and herbaceous species, and of *A. chilensis* regeneration.

The cover of herbaceous species was transformed using the arcsine square root. Diversity was calculated with the Shannon-Wiener's Index (H'). Statistical treatment of data was carried out with the program Biometry (Sokal and Rohlf, 1995). Data homogeneity was first checked with a Bartlett's test. As some data were not homogeneous and the number of repetitions was relatively small, we used the Kruskal-Wallis non parametric test.

Results

Analysis of the community

Most species were herbaceous (table 1) in spite of the low total cover of this life form. Nearly all herbaceous species had covers < 5%, except for the native specie *Acaena ovalifolia* Ruiz *et* Pav., widely distributed in the Patagonian region and the *Holcus lanatus* L., an exotic and cosmopolitan grass. Fifty percent of the herbaceous species were exotic. The shrub layer had a mixed character (table 1), with a great quantity of small size shrubs where the most abundant species were *Maytenus chubutensis* (Speg.) Lourteig et O'Donell et Sleumer, *Maytenus boaria* Molina and *Schinus patagonica* (Phil.) I. M. Johnst. All woody species were natives. *A. chilensis* dominated the tree canopy (82%) and a few other trees of the following species were found: *Lomatia hirsuta* (Lam.) Diels *ex* J. F. Macbr., (9%), *S. patagonica* (5%) and *Nothofagus antarctica* (G. Forst.) Oerst (4%).

Diversity variation with distance to edge

Diversity of woody species was superior into the forest, decreasing slightly near the edge (p = 0.0289). The lowest diversity values for woody species were found outside the forest (figure 2a). The diversity varied continuously along the transects, indicating that this variable is influenced by the edge effect at least 70 m into the forest.

The richness of native species increased significantly in the core forest (p = 0.0053) (figure 2b). The diversity of native species started being constant 30 m inside the forest.

Table 1. Plant species, growth forms, and status

Species	Status	Growth form
Acaena ovalifolia Ruiz *et* Pav.	native	herbaceous
Acaena pinnatifida Ruiz *et* Pav.	native	herbaceous
Acaena splendens Gillies ex Hook. et Arn.	native	herbaceous
Adenocaulon chilense Less.	native	herbaceous
Afin Agropyron patagonicum (Speg.) Parodi	native	herbaceous
Afin Aira praecox L.	exotic	herbaceous
Afin Barbarea intermedia Boreau	exotic	herbaceous
Afin Erigeron schnackii Solbrig	native	herbaceous
Afin Trifolium aureum Pollich	exotic	herbaceous
Cerastium glomeratum Thuill.	exotic	herbaceous
Erodium malacoides (L.) L'Hér.	exotic	herbaceous
Fragaria chiloensis (L.) Duchesne f.	native	herbaceous
Galium fuegianum Hook. f.	native	herbaceous
Gavilea odoratissima Poepp.	native	herbaceous
Geranium berterianum Colla	native	herbaceous
Holcus lanatus L.	exotic	herbaceous
*Galium sp.*L. Maror	native	herbaceous
Calceolaria sp. L.	native	herbaceous
Myosotis arvensis (L.) Hill	exotic	herbaceous
Myosotis scorpioides L.	exotic	herbaceous
Osmorrhiza chilensis Hooker et Arnott	native	herbaceous
Phacelia artemisioides Griseb.	native	herbaceous
Plantago sp L.	exotic	herbaceous
Prunella vulgaris L.	exotic	herbaceous
Rorippa nasturtium-aquaticum (L.) Hayek	exotic	herbaceous
Rumex acetocella L.	exotic	herbaceous
Taraxacum officinale Weber ex F. H. Wigg.	exotic	herbaceous
Trifolium repens L.	exotic	herbaceous
Verbascum thapsus L	exotic	herbaceous
Vicia sp. L.	native	herbaceous
Viola sp. L.	native	herbaceous
Aristotelia chilensis (Molina) Stuntz	native	shrub
Austrocedrus chilensis (D. Don) Pic. Serm. et Bizzarri	native	tree
Berberis heterophylla Juss. Ex Poir	native	shrub
Cynanchum descolei T. Mey.	native	creeper
Diostea juncea (Gillies et Hook.) Miers	native	shrub
Lomatia hirsuta (Lam.) Diels ex J. F. Macbr.	native	shrub
Maytenus boaria Molina	native	tree
Maytenus chubutensis (Speg.) Lourteig et O'Donell et Sleumer	native	shrub
Mutisia decurrens Cav.	native	creeper
Mutisia spinosa Ruiz et Pav.	native	creeper
Nothofagus antarctica (G. Forst.) Oerst	native	shrub
Ribes cucullatum Hook. et Arn.	native	shrub
Ribes maguellanicumm Poir.	native	shrub
Schinus patagonica (Phil.) I. M. Johnst.	native	shrub

Abundance variation with distance to edge

The quantity of woody species increased towards the core forest (p = 0.0149). The greatest differences were found between the grassland and the area placed 30 m inside the forest (figure 2c). Beyond that distance the diversity increased (figure 2a), but the number of individuals for each specie was smaller.

The abundance of herbaceous species increased towards the grassland (p = 0.0197). Main differences

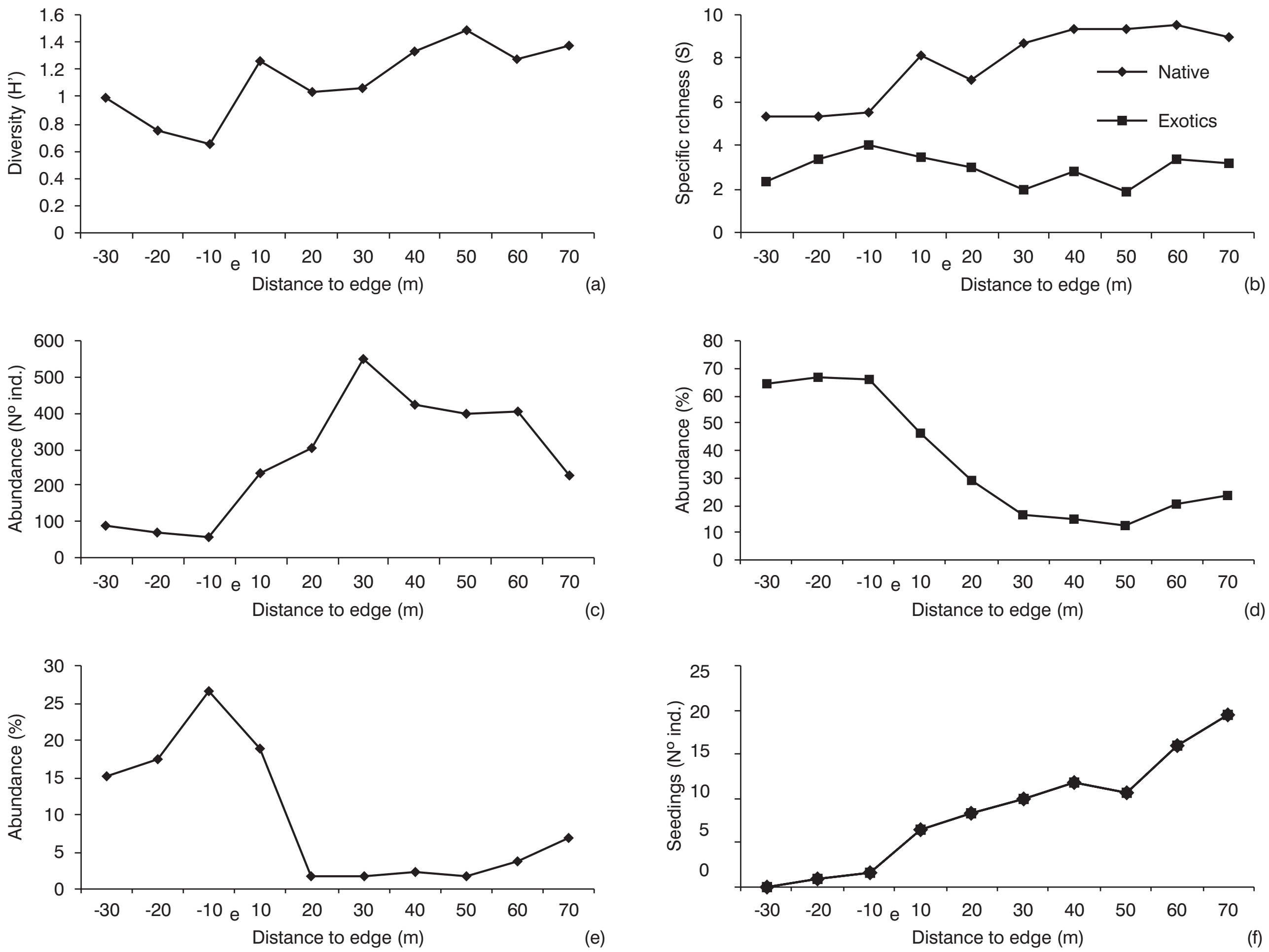

Figure 2. Attribute variation according to distance to edge, the edge line is indicated with «e», the negative values are distances outside the forest, the positive values are distances into the forest. The data from the three edge situations were averaged. (a) Diversity of woody species, (b) Specific richness, (c) Abundance of woody species, (d) Abundance of herbaceous species, (e) Abundance of *A. ovalifolia,* (f) Regeneration of *A. chilensis.*

occurred between the grassland and the area located 30 m after the edge (figure 2d). Regarding this attribute the edge effect lasted no more than 30 m.

Edge-restricted species were not detected and only one specie, *A. ovalifolia,* increased towards the grassland ($p = 0.0340$). The greatest differences were found between the grassland and the area located 20 m after the edge (figure 2e).

Variation of A. chilensis regeneration with distance to edge

The *A. chilensis* regeneration was more abundant into the forest than in the edge, decreasing with distance to edge ($p = 0.0408$). The greatest differences were found in both endings of the transects, the grassland and the core forest (figure 2f).

Discussion

Gobbi (1994) demonstrated that there was a slow recovery of the shrub stratum in an *A. chilensis* forest disturbed by fire 15 years before. We detected a decrease in the diversity and abundance of native shrubs in the edge of disturbed sites, this distribution model of the native shrubs composing the under canopy of the *A. chilensis* forest could be correlated with more favorable forest core conditions.

We found that *A. chilensis* edges represent a better environment for the development of herbaceous species than the forest core, due to the fact that the herbaceous flux is controlled by light availability (Matlack, 1994; José *et al.,* 1996). In addition, according to Damascos *et al.* (1999) and Gobbi (1994) there is also a quick recovery of herbaceous stratum in *A. chilensis* forests with disturbances.

On the other hand it has been reported that a typical vegetation response to the edge environment in forest remnants is the increase of exotic species (Laurence and Yensen, 1991; Brothers and Spingarn, 1992; Fraver, 1994 in Gehlhausen *et al.,* 2000). We found that richness of exotic species tended to increase slightly near the edge, but with an uniform distribution. On the contrary, the native species increased towards the forest. Fraver (1994) indicated that edges are more susceptible of being covered by weeds and other exotic species than the forest core. Over there exotic species do not constitute a significant component, perhaps because the edge itself constitutes a physical barrier that must be crossed by the seeds in dispersion (Cadenasso and Pickett, 2000). The uniform distribution of exotic species in our transects could be explained by two factors: cattle presence and timber extraction. Cattle dung increases seed dispersion towards the forest core, whereas trampling and deposition of organic matter may contribute in the intensification of disturbance levels. In addition, as some authors have pointed out (Brothers and Spingarn, 1992; Fox *et al.,* 1996), timber extraction also contributes to an increase in the disturbance levels and to the opening of canopy gaps favoring light availability and the subsequent store of herbaceous species.

The knowledge about the edge effect on *A. chilensis* regeneration could provide valuable information about the recovery of adjacent habitats during the first years of succession. The regeneration decreased in the edge, and 30 m outside the forest no regeneration was detected. Similar results were obtained in other forest ecosystems such as the dry subtropical forest (Aizen and Feinsinger, 1994) and the tropical rain forest (Benitez Malvido, 1998).

As indicated by some authors (Kapos, 1989; Kapos *et al.,* 1993; Camargo and Kapos, 1995) the decrease of the regeneration in the edge sector could be attributed to different factors, such as the environment desiccation resulting from an increase in the levels of wind and radiation that affect the settling of seeds in need of higher humidity.

In this study it could be added that a high supply of herbs in the edge sector in addition to a low quantity of shrubs and the effect of cattle that prune and tramp, decrease the possibility of *A. chilensis* regeneration.

Shrubs could also act as a natural barrier preventing cattle aggression at the stage that follows germination. Gobbi and Schlichter (1998) suggested that the presence of shrubs protects regeneration and Kitzberger *et al.* (2000) found that the emergency and establishment of one year old *A. chilensis* regeneration was superior in shrubby places. Mortality of *A. chilensis* regeneration was greater in places where shrubs had been removed, especially during years with severe drought (Letourneou *et al.,* 2003). It could be expected that if the quantity of shrubs increases towards the forest core, regeneration would also increase.

In this study both parameters showed an increase towards the forest core. During the first years of the succession, there is a tendency to retraction in the forest edge, so it can be expected that the size of the remnants will diminish. If the factors driving to forest fragmentation continued operating, the long-term permanency of *A. chilensis* would be at risk. Any strategy of forest recovery from fragmented areas should involve the chance to plant native shrubs and *A. chilensis* in the edges surroundings the remnants, in order to guarantee the expansion of the forest towards the adjacent habitats. Futhermore, cattle presence should be completely banned to minimise the effect over the plant community.

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