

Precarious conservation status of *Pilgerodendron uviferum* forests in their northern distribution in the Chilean Coastal Range

Estado de conservación precario de los bosques *Pilgerodendron uviferum*, en su límite norte en la Cordillera de la Costa Chilena

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SUMMARY

Pilgerodendron uviferum, ciprés de Las Guaitecas, is a long-lived member of the family *Cupressaceae*; it is dioecious, and endemic to the temperate forests of South America. Its geographic range extends over 1,600 km, from 39°35'S (Valdivia Province, Chile) to 54°20'S (Cape Horn), making it the conifer with the southernmost distribution in the world. North of 42° S latitude, the species is restricted to small, discrete forest stands in waterlogged soils. This paper describes four previously undocumented stands of *P. uviferum* in south-central Chile (39°50') –extending the known northern limit of the species in the Chilean Coastal Range (CCR)– and highlights its precarious conservation status. These small stands (< 2 ha) are isolated within a matrix of pastures and exotic forest plantations, and are subject to chronic disturbance by livestock grazing, logging, and burning. On the basis of dead burned snags and stumps, we estimated that recurrent burning and logging have resulted in a 57% loss of *P. uviferum* stems, and an 80% loss of basal area in these stands. Current land use regimes in the study area are causing multiple threats to the viability of these stands. We recommend to develop a restoration program in order to preserve these geographical outlying *P. uviferum* populations.

Key words: forest remnants, swamp forests, threatened conifer, wetlands.

RESUMEN

Pilgerodendron uviferum, ciprés de Las Guaitecas, es una especie dioica, miembro de la familia de las *Cupressaceae*, endémica de los bosques templados de Sudamérica. Su distribución geográfica se extiende cerca de 1.600 km, desde los 39°35'S (provincia de Valdivia) hasta los 54°20' S (Cabo de Hornos), convirtiéndose en la conífera con distribución más austral de mundo. Al norte de los 42°S la especie se restringe a pequeños fragmentos de bosques ubicados en suelos inundados. El artículo describe cuatro rodales de *P. uviferum* no documentados en el centro-sur de Chile (39°50' S), extendiendo el límite norte de la especie en la Cordillera de la Costa de Chile (CCR), y resaltando su precario estado de conservación. Estos pequeños rodales (< 2 ha) se encuentran aislados entre sí e inmersos en una matriz de praderas y plantaciones de especies exóticas, siendo permanentemente sujeto de alteraciones crónicas por ramoneo, cortas y fuego. Sobre la base de árboles muertos en pie y tocones, se estimó que las quemadas recurrentes y cortas tienen como resultado una pérdida de 57% de los árboles y 80% del área basal en los rodales. Actualmente el régimen de uso del suelo del área de estudio es causa de múltiples amenazas para la viabilidad de estos rodales. Se recomienda implementar un programa de restauración a fin de preservar estas poblaciones geográficamente marginales.

Palabras clave: bosques remanentes, bosques húmedos, conífera amenazada, ñadis.

INTRODUCTION

The temperate rainforests of Chile and Argentina are considered to be among the 25 highest priority areas for the conservation of biodiversity in the world (Gil *et al.* 1999, Myers *et al.* 2000). This is due to their high level of endemism (ca. 50%), and to the dramatic reduction of their original habitat area (ca. 70%) that has occurred as

a consequence of anthropogenic impacts (Smith-Ramírez 2004, Gardner *et al.* 2006), which is equivalent to the reduction in area experienced by these forests during the last glaciation (Armesto *et al.* 1994, 1998).

The three endemic and monotypic members of the *Cupressaceae* family found in this area have serious conservation problems (Veblen *et al.* 1976, Walter and Gillett 1998, Hilton-Taylor 2000). Among these spe-

cies, ciprés de Las Guaitecas (*Pilgerodendron uviferum* [D. Don.] Florin) is the world's southernmost occurring conifer species, covering the greatest latitudinal distributional range (39° 35' - 54° 20'S; ca. 1,600 km), mainly in Chile, and existing as scattered populations in Argentina (Martínez 1981, Szeicz *et al.* 2000, Rovere *et al.* 2002). *Pilgerodendron uviferum* is a dioecious conifer that is a characteristic arboreal element of Chile's sub-Antarctic forests and Magellanic moorlands; it occupies humid sites with flat topographies in poorly drained areas with high water tables (Pisano 1977, Cruz and Lara, 1981, Moore 1983, Villagrán 1988, Allnutt *et al.* 2003). The wood of *P. uviferum* is highly resistant to decay (Woda 2003), so that fallen logs and snags may persist for decades or even centuries. It has well-defined tree rings and its radial growth is sensitive to climatic variations (Roig and Boninsegna 1991, Roig 1992, Boninsegna 1992). For these reasons, it has been utilised for palaeoclimate reconstruction (Roig 1991, Roig and Boninsegna 1991, Szeicz *et al.* 2000, 2003).

Pilgerodendron uviferum has been severely exploited, beginning in the 17th century (Martínez and Muñoz 1988), due to the excellent quality of its wood (Diaz-Vaz 2002). Human-set fires have also severely reduced the area of these forests (Cruz and Lara 1981). Actually, most *P. uviferum* forests have standing burnt trees, or have been logged and have been dramatically affected by extensive livestock grazing, and as a result vast areas have failed to regenerate (Cruz and Lara 1981, Rovere *et al.* 2002, Allnutt *et al.* 2003, Bannister 2004). Because of these threats, *P. uviferum* has been classified as vulnerable (Walter and Gillett 1998, Farjon and Page 1999, Hilton-Taylor 2000) by the IUCN (World Conservation Union), and has been included in Appendix 1 of the CITES convention, which regulates the international trade of threatened species. The relatively easy access afforded by the construction of new roads through pristine *P. uviferum* stands in the Aisén Region (48° 35' - 50° 20'S) has facilitated further logging activities in the last few years.

North of 42° S in Chile, the species is restricted to small, isolated populations (Donoso 1993, see figure 1). These populations, considered to be remnants from Pleistocene glacial refugia (Villagrán 1991, Villagrán and Armesto 2005), are genetically different from the southern more contiguous populations (Premoli *et al.* 2002, Allnutt *et al.* 2003). Corral Bay (40° S) has been documented as the northern distributional limit of *P. uviferum* in the Chilean Coastal Range (CCR) (CONAF 2000). However, there has been no previous documentation of the presence of this species north of this locality. Within this context, the main objectives of this study are: (i) to locate *P. uviferum* populations north of its documented distributional range in the CCR, (ii) to describe *P. uviferum* stand structure, composition, regeneration, radial growth and sexual ratio, and (iii) to evaluate the anthropogenic threats to their persistence.

METHODS

Study area. The study area extends between 39° and 40°S in the CCR, and it covers approximately 4,500 km². The forest landscape here is dominated by exotic plantations of *Pinus radiata* D. Don and *Eucalyptus spp.* (figure 1).

This area has a temperate climate with a Mediterranean influence. The study sites occupied by *P. uviferum* receive between 2,500 mm (low elevation 0 to 300 m a.l.s.) and 6,000 mm (high elevation 300 to 1000 m a.l.s.) of annual precipitation, concentrated in winter months (June-August). The mean annual temperature varies between 10 and 12 °C (Di Castri and Hajek 1976, Woda 2003). *P. uviferum* grows in poorly-drained soils that are constantly saturated with water. In the northern portion of the CCR (40°10' S) Lara *et al.* (1999a) documented the presence of *P. uviferum* in the least productive sites presenting very acidic organic soils (pH from 3.5 to 4.7), classified as Gleysols and Histosols (FAO-UNESCO 1971, Cruz and Lara 1981).

Data collection and analysis. To locate the stands, the potential sites were delineated; these sites were characterized by nearly flat areas in portions of watersheds presenting little outflow; conditions that can be found in headwaters and waterlogged lowlands within the study area. Based on local knowledge and on 1:20,000 scale aerial photographs, the presence of *P. uviferum* small forest stands was possible to be located in the field. The exact position for each stand located stand was recorded using a GPS, and its area was estimated.

Three 20x20 m plots were set up at each study stand where the diameter at breast height (DBH), total height (TH), and diameter at stump height at 30 cm above ground (DSH) were measure for all *P. uviferum* individuals > 5 cm. The basal area (the total cross-sectional area at breast height of all the trunks, expressed in m² ha⁻¹) of all individuals in each stand previous to logging was estimated. Linear regression analysis was carried out, using the DSH and DBH variables, to reconstruct the residual structures of the *P. uviferum*-stands. To assess the quality of the regression *r*² (coefficient of determination), MSE (mean square error) and *P* (probability of the F value) were used.

In the interior of each plot, six 2 x 2 m subplots (24 m² in each plot and 72 m² in each stand) were installed, where seedlings < 2 m in TH, and saplings ≥ 2 m in TH and < 5 cm DBH of every tree species were counted, following the methodology of Fraver *et al.* (1999). Paired-sample *t* tests were also carried out to compare the seedling and sapling density of *P. uviferum* with that of other species on sites.

Given the dioecious character of *P. uviferum*, the individual trees bearing visible reproductive structures (male and female cones), during spring-summer, were counted in each plot. Differences between male and female ratios (M:F) were determined with χ^2 analysis based observed vs. expected (1:1) frequencies (Núñez *et al.* in press). Two increment cores were extracted from each of three domi-

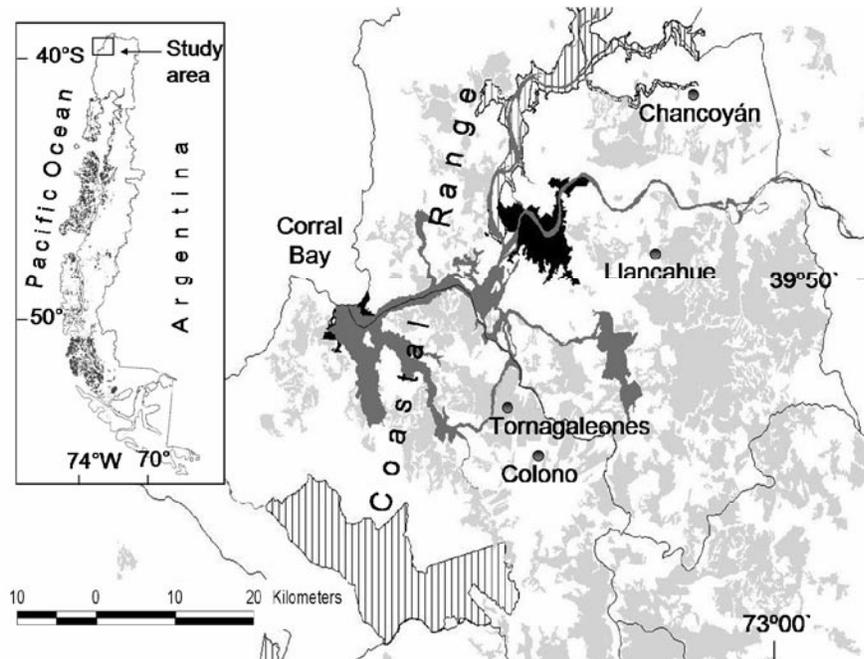


Figure 1. Location of the four *P. uviferum* stands studied in the Coastal Range Cordillera indicated by gray dots (Chancoyán, Llancahue, Tornagaleones and Colono). Exotic plantations of *Eucalyptus spp.* and *Pinus radiata* are indicated with light grey, rivers in dark grey, the city of Valdivia in black, and government protected areas are represented by a polygon with straight line surface. In the small-left map the shaded area shows the distributional range in Chile of *P. uviferum*.

Localización de los cuatro rodales de *P. uviferum* estudiados en la Cordillera de la Costa (puntos grises), las plantaciones (*Eucalyptus spp.* y *Pinus radiata*) en gris claro, ríos en gris oscuro, ciudad de Valdivia en negro y áreas protegidas por el gobierno chileno con achurado. En el mapa de la izquierda, el área sombreada muestra la distribución natural de los bosques de *P. uviferum*.

nant trees per plot (from nine individuals in each stand), to determine the age and mean annual diameter increment (MAI) for each stand. To verify the statistical differences in diameter structure, height, and MAI, an ANOVA and the Tukey HSD paired means test (Steel and Torrey 1988) were carried out.

The land-uses of the surrounding matrices in which the stands were located (e.g. pastureland, forest plantation, old growth native forest, second growth native forest) were described. To quantify the disturbances that have affected each stand, we followed the criteria proposed by Rovere *et al.* (2002), which consider human-set fires, logging, livestock grazing, and drainage works. Qualitative values were assigned to these alterations, ranging from 0 (no apparent alteration) to 1, 2, and 3 (alterations of lesser to greater intensity).

RESULTS

The study sites are isolated distinctive forest stands, with areas < 2 ha, located at elevations between 5 and 315 m a.s.l. (figure 1, table 1).

Table 1. General characteristics of the studied forests stands. Características generales de los rodales estudiados.

Stand	Aspect	Slope %	Elevation m a.s.l.	Area (ha)	Ownership
Chancoyán	None	0	5	0.76	Private landowner
Colono	NE	6	205	1.91	Private landowner
Llancahue	SE	8	300	1.82	Public Land
Tornagaleones	NE	12	315	1.54	Timber Company

The stands show evidence of extensive anthropogenic disturbance. The Colono and Tornagaleones stands are the most disturbed due to high levels of logging and livestock grazing, impacts to the water table, and past fires. Concerning land uses, Chancoyán (table 2) is surrounded by a matrix of evergreen broadleaf forest growing on a soil with a high water table, locally known as “hualve”. At present, the landowners are building ditches to drain the soil and replacing this native forest matrix for agricultural land uses (subsistence farming and livestock grazing). Seventy five percent of the perimeter of the Colono stand is occupied

by *Pinus radiata* plantations that extend to the very edge of the stand. The remaining 25% of the stand's perimeter is subjected to chronic livestock grazing. Seventy percent of the Llancahue stand's perimeter is occupied by second-growth native forest that regenerated after human-set fires burned the area ca. 50 to 70 years ago. The remaining 30% of the stand's margin limits with an old pasture, which is being colonized by native shrubs, due to overgrazing by livestock, is being converted into a dense thicket. Finally, the Tornagaleones stand is completely surrounded by *Eucalyptus nitens* plantations (table 2).

Table 2. Degree of disturbance in the different stands, where: 0 = no apparent disturbance, and 1, 2, and 3 = disturbance from lesser to greater intensity (see Soto 2004).

Grado de alteraciones en los diferentes rodales, donde: 0 = alteración no aparente, y 1, 2 y 3 = alteraciones de menor a mayor intensidad.

Stand	Fire evidence	Livestock grazing	Logging	Water table impacts
Chancoyán	0	3	0	3*
Colono	2	3	3	2#
Llancahue	2	3	2	1
Tornagaleones	3	3	3	3#

* Anthropogenic drainage works. # Perimeter with forest plantation with high evapotranspiration rates.

The Chancoyán and Llancahue sites exhibit multispecific multilayered forest stand structures, while Colono and Tornagaleones sites exhibit simple stand structures dominated by *P. uviferum* (table 3).

Table 3. Summary of the stand structure attributes.
 Resumen de los atributos estructurales de los rodales.

Stand	Species	Nº trees ha ⁻¹	Basal Area m ² ha ⁻¹	Mean DBH (cm) ± SD	Age (yr)	MAI* (cm/yrs)	Mean# TH (m) ± SD
Chancoyán	<i>P. uviferum</i>	700	6.6	11.2±5.2	71	0.299a+	8.6±2.3
	<i>Gevuina avellana</i>	125	1.1	9.7±2.5	–	–	6.3±2.7
	<i>Drimys winteri</i>	125	0.5	6.7±1.9	–	–	4.2±0.6
	<i>Tepualia stipularis</i>	475	3.0	8.1±2.4	–	–	6.7±1.2
	<i>Weinmania trichosperma</i>	75	4.5	8.1±13.3	–	–	6.7±1.7
Colono	<i>P. uviferum</i>	175 (96)	1.5 (6.1)	8.9±4.2	70	0.272a	4.5±0.9
Llancahue	<i>P. uviferum</i>	1,325 (325)	4.7 (6.7)	8.3±4.7	298	0.079c	3.9± 3.9
	<i>Nothofagus nitida</i>	200	3.2	8.4±4.8	–	–	6.1±3.8
	<i>Tepualia stipularis</i>	825	3.4	7.9±4.4	–	–	2.8±2.5
Tornagaleones	<i>P. uviferum</i>	420 (160)	3.1 (2.3)	8.2±4.5	48	0.200b	3.9±0.8

* Mean annual diameter increment, at breast height. # Total Height. + Different letters for growth indicate statistically significant differences (Tukey HSD test, $P < 0.05$), $n = 18$ samples per stand. Numbers between parentheses indicate values of density and basal areas of dead individuals. The sums of the values between parentheses and the preceding values in each cell indicate the values previous to anthropogenic disturbances.

Chancoyán has the greatest mean diameter ($11.2 \pm$ Standard Deviations (SD) 5.2cm) and height (8.6 ± 2.3 m). In Llancahue, *P. uviferum* shares the dominance of the canopy with *Nothofagus nitida* (table 3). The stands do not exhibit statistically significant differences in mean diameters (ANOVA, $F_{4,07} = 0.337$, $P = 0.7988$) or in mean heights ($F_{4,07} = 2.8811$, $P = 0.1077$) of *P. uviferum* and other tree species (table 3).

Three stands (Colono, Llancahue, and Tornagaleones) have dead *P. uviferum* trees that were killed by fires and logging activities (table 2). Reconstruction of the tree diameters provided a highly efficient fit and validation ($P < 0.0001$; figure 2). The reconstructed mean diameter was 18.8 ± 10.5 cm, and the present mean DBH 7.4 ± 3.4 cm, which yields highly significant differences ($t = 7.4$, $df = 48$, $P < 0.0001$). However, in the Tornagaleones stand the present diameter (9.8 ± 8.6 cm) is greater than the diameters for cut and dead trees (8.6 ± 3.3 cm), which does not yield significant differences ($t = 0.41$, $df = 10$, $P = 0.687$; table 3).

Differences in mean diameter increment (MAI) of *P. uviferum* were highly significant among sites ($F_{3,49} = 33.44$, $P < 0.0001$). However, Chancoyán and Colono did not have statistically significant differences in mean growth (Tukey HSD test; $P = 0.203$, table 3).

The regeneration of *P. uviferum* was significantly different from that of other tree species as a group for Colono, and not different for Tornagaleones (table 4). On the other hand, in Chancoyán and Llancahue the regeneration of other tree species was significantly different from that of *P. uviferum* (table 4). *Pilgerodendron uviferum* dominated the total number of seedlings and saplings in Colono and Tornagaleones, representing 66.8% and 71.8%, respec-

tively. The number of seedlings and saplings of the other tree species in the least disturbed stands, Chancoyán and Llancahue, was 72.3 and 71.8%, respectively, the remainder being *P. uviferum* (table 4).

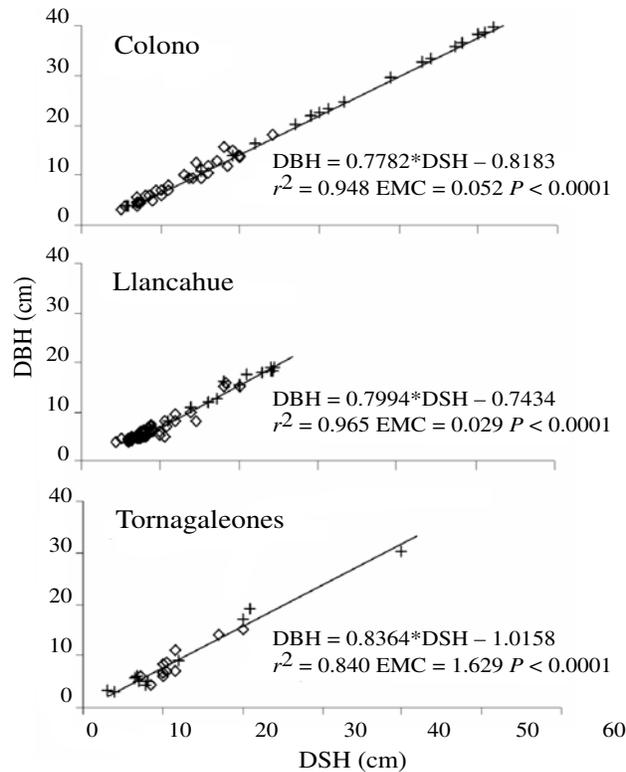


Figure 2. Relationships between diameter at stump height (DSH) and diameter at breast height (DBH), and equations for the reconstructions of lost structure of *P. uviferum* stands in CCR. Diamond shows living trees, and crosses show dead and cut trees.

Relación entre DSH (diámetro a la altura del tocón) y DBH (diámetro a la altura del pecho), y ecuación para la reconstrucción de la estructura perdida de los rodales de *P. uviferum* en la Cordillera de la Costa. Diamantes muestran árboles vivos, y cruces muestran árboles muertos y cortados.

Table 4. Regeneration (seedlings + saplings) of *P. uviferum* and other tree species.

Regeneración (plántulas y brinzales) de *P. uviferum* y otras especies arbóreas.

Stands	<i>P. uviferum</i>	Others species	t - value
Chancoyán	972 ± 635	9,442 ± 1,048	-15.24**
Colono	4,860 ± 1,577	971 ± 240	5.03*
Llancahue	694 ± 240	2,221 ± 240	-5.50*
Tornagaleones	1,805 ± 240	694 ± 240	3.99ns

All stands with 2 degree of freedom, ns: not significant * $P < 0.05$, ** $P < 0.01$.

The presence of male cones in *P. uviferum* trees was greater ($21.0 \pm \text{SD } 13.5$) than that of female cones ($10.0 \pm \text{SD } 4.1$) in every stand. In percentage, the presence of male individuals varied between 61 and 72% of all of the trees with recognizable reproductive structures in each stand (Table 5). The presence of males is highly different in relation to female for all study stands ($P = 0.009$). The most disturbed stands, Colono and Tornagaleones have differences between male vs. female ratios ($P < 0.05$), but these ratios increased in 2.3 for Chancoyán and 2.6 for Llancahue ($P < 0.001$), those being the less disturbed stands (table 5).

Table 5. Flowering *P. uviferum* individuals and sex ratio M:F (Male:Female) in the study stands.

Individuos florecidos de *P. uviferum* y razón sexual en los rodales de estudio.

Sites	Sampled trees*	Flowering	Male	Female	M:F
Chancoyán	84	33 (39.3%)	23 (69.7%)	10 (30.3%)	2.3**
Colono	21	13 (61.9%)	8 (61.5%)	5 (38.5%)	1.6*
Llancahue	160	54 (33.7%)	39 (72.2%)	15 (27.8%)	2.6**
Tornagaleones	50	24 (48%)	14 (58.3%)	10 (41.7%)	1.4*
Mean ± SD	78.7 ± 59.9	31.0 ± 17.4	21.0 ± 13.5	10.0 ± 4.1	2.1**

* all individuals identified in the stands (three plots per stand). ns: not significant * $P < 0.05$, ** $P < 0.01$.

DISCUSSION

The four studied forest stands are the northernmost known *P. uviferum* populations in the Coastal Range of south-central Chile ($39^{\circ} 45' - 39^{\circ} 57' \text{ S}$). In Llancahue ($39^{\circ} 49' \text{ S}$), *P. uviferum* is associated with *Nothofagus nitida* (Phil.) Krasser., whose northern distribution limit was formerly thought to be located within the Valdivia National Reserve 40° S (CONAF 2000). Therefore, Llancahue would be the new northernmost documented occurrence of *N. nitida* in the CCR, 80 km from its previously reported northern distribution limit. *N. nitida* is an evergreen species, restricted to southern Chilean forests with oceanic climatic influences, that often occurs on waterlogged soils at low elevations, where it can coexist with *P. uviferum*, as it does in Llancahue.

The study stands are found within highly disturbed matrices (table 2), which range from fast-growing exotic forest plantations to agriculture and pasturelands. In three of the stands (Colono, Llancahue and Tornagaleones) evidence of past human-set fires was found, affecting stand structure and species composition (tables 2 and 3). *Pilgerodendron uviferum* trees of all sizes have been cut for timber at these sites. Trees from the larger diameter classes in Colono and Llancahue were used for lumber, and trees from the smaller diameter classes in Tornagaleones

were used as fence poles (figure 2). The stand structures have been severely modified, as indicated by the reduction in the number of trees per ha and the basal area by up to 57%, and up to 80%, respectively (table 3).

Colono and Tornagaleones stands, despite having been severely degraded (table 2), have higher percentages of *P. uviferum* seedlings and saplings over the total, compared to the other stands (table 4). The successful regeneration of *P. uviferum* in these disturbed sites with open canopies is explained by the relatively shade-intolerant character of the species (Donoso 1993, Lara *et al.* 2006). This would indicate that these stands are undergoing a slow process of recovery following the described anthropogenic disturbances. It has been claimed that *P. uviferum* recovery in disturbed areas is only possible if the soils remain waterlogged (Plaza 2001, Szeicz *et al.* 2003). Therefore, matrices of fast-growing *Pinus radiata* plantations, which have high evapotranspiration rates (Vertessy 1999, Oyarzún and Huber 1999, Oyarzún *et al.* 2005), could retard or hamper *P. uviferum* regeneration in the stands surrounded by such plantations. Drainage ditches constructed within matrices dedicated to agriculture and pastures may also have a negative impact on *P. uviferum* regeneration (tables 2 and 4). These effects would lead to the decrease of the dominance of this species in these marginal, highly fragmented stands, and its eventual replacement by other species. Nevertheless, long-term research is needed to properly assess these trends.

Only between 34 and 62% of mature *P. uviferum* trees bear reproductive structures at each stand. Between 27 and 42% of these reproductive individuals bear female cones (table 5). The scarcity of reproductive structures could be due to the stressful conditions being experienced by these individuals at the northern limit of the species geographic range as is the case for another *Cupressaceae* *Austrocedrus chilensis* (D. Don.) Pic. Serm. *et* Biz. in its northern limit in Argentina (Rapoport and Drausal 1979). In all stands the sex-ratio was balanced towards male individuals (table 5). However, in the most disturbed stands such as Colono and Tornagaleones, the sex-ratio tends to be 1:1, but in those presenting a low percentage of flowering trees, it is higher (13 and 24%, respectively). In the case of the less disturbed stands as Chacoyán and Llancahue, the number of flowering trees is higher (33 and 54%, respectively) showing an unbalanced sex-ratio with higher proportion of male trees. On the other hand, a recent study of biogeographical gradient of sexes in *A. chilensis* shows that female trees are found in moistured and shaded slopes (east and south) sites. However, male trees prefer xeric and high-radiation slopes (west and north) sites (Núñez *et al.* in press). Our study shows that stands with higher levels of *P. uviferum* regeneration also had a greater share of female individuals, and vice versa; a possible indication of the importance of female individuals to assure seed production and seedling recruitment (table 4 and 5). Nevertheless, *P. uviferum* recruitment by layering and root

suckering has been reported in Chiloé Island (Cruz and Lara 1981, Lara *et al.* 2006).

Among the southern South American *Cupressaceae* species, *P. uviferum* has the highest genetic variability among populations specially in its northern limit, where our study stands are located (Allnutt *et al.* 2003, Premoli *et al.* 2001, 2002). Moreover, *P. uviferum* is considered to be an excellent high resolution proxy for the reconstruction of past climates, due to its extensive distribution, its longevity (850 years), and to the marginality of the environments in which it grows (Roig 1991, Szeicz *et al.* 2000, 2003). These characteristics, in addition to the anaerobic reducing conditions in the soil and subsoil, which are conducive to the preservation of plant macrofossil and pollen records, lead us to emphasize the importance of the conservation of these unique stands, which have been considered as refugia for the flora from the last Pleistocene glaciation (Villagrán 1991, Premoli *et al.* 2002, Allnutt *et al.* 2003).

These stands are located in an area that due to its biodiversity and endemism is of high priority for conservation on a local, regional and global scale (Armesto *et al.* 1998, Myers *et al.* 2000, Lara *et al.* 2003, Smith-Ramírez 2004, Conservation International 2005). Therefore, it is urgent to work toward the protection and restoration of these stands. Conversion of native forests to agriculture, pasture lands, and forest plantations in the valdivian rainforest Ecoregion (Lara *et al.* 1999b) increase the threats to these small, marginal forest stands (figure 1). The creation of new protected areas, as well as the development of conservation and restoration programs directed towards these northernmost stands should be given a high priority.

Future research should address the location of new stands and studies on the genetic variability of the stands and compare these with other genetic studies that have been carried out on *P. uviferum*. As a result of our studies, it is clear that urgent action should be taken on the protection and restoration of *P. uviferum* stands located in its northernmost distribution in the CCR. Such plans should involve the different stakeholders, such as the Chilean Forest Service (CONAF), landowners, forest companies, research institutions and non governmental organizations. Fencing, establishment of buffer areas around the stands, plantations with seedlings from local seed sources, and effective protection against fire, are among the activities that should have priority within any conservation strategy.

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