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Cypress mortality (mal del cipres) in the Patagonian Andes: comparisons with similar forest diseases and declines in North America

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Summary

Widespread mortality of Cordilleran cypress (*Austrocedrus chilensis*) occurs in developed and pristine forests in south-western Argentina and possibly south-eastern Chile. Affected trees may die rapidly but mortality is commonly preceded by several decades of severely restricted radial stem growth. Roots are often affected by one or more types of decay. Cypress mortality, locally termed 'mal del cipres', is similar to a major forest disease in North America: Port-Orford-cedar (*Chamaecyparis lawsoniana*) root disease in Oregon and California and a major tree decline: Alaska yellow-cedar (*Chamaecyparis nootkatensis*) decline in south-east Alaska. This paper discusses several hypotheses concerning mal del cipres and compares current forest decline research in Patagonia with North America.

1 Introduction

Cordilleran cypress (*Austrocedrus chilensis* (D. Don) Florin and Boutleje) is an evergreen conifer that grows between 36°30′ and 43°35′S latitude on the eastern slopes of the Andes in Argentina and between 32°39′ and 44°S latitude on the western slopes of the Andes in Chile (Veblen et al. 1995). In Argentina, it grows in the Andean foothills in a strip only 60–70 km wide. This limited east–west range actually includes a broad moisture gradient to which Cordilleran cypress is well adapted. In the west, this species is a component of the mesic southern beech (*Nothofagus* spp.) forests that receive more than 150 cm/year of precipitation. In the east, it occurs in open, more xeric forests that receive less than 60 cm/year precipitation (Veblen et al. 1992). The closest ecological counterpart to Cordilleran cypress in North America is probably incense-cedar (*Libocedrus decurrens* Torr.), which grows across a similar moisture gradient in the Cascade Range of Oregon and in the Sierra Nevada of California (Burns and Honkala 1990).

Widespread mortality of Cordilleran cypress occurs in Patagonia and has been locally termed 'mal del cipres de la cordillera' (Cordilleran cypress sickness) or 'secamiento del cipres' (cypress drying). The cause of the mortality is unknown. Mal del cipres was first noticed in 1948 on Victoria Island in Nahuel Haupi National Park (Havrylenko et al. 1989). Throughout the range of Cordilleran cypress in Argentina, mal del cipres can occur over large areas. It occurs within major cities, especially near new construction and in poorly drained areas. Mal del cipres also occurs in pristine forests in Nahuel Haupi National

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Park, again primarily in poorly drained areas (Fig. 1). The presence of mal del cipres in Chile is unknown. In Argentina the mortality is sufficiently widespread in some areas to potentially eliminate Cordilleran cypress as a viable species. The objective of this paper is to describe the current state of knowledge about this new forest problem, present several hypotheses regarding the cause of mal del cipres, and compare this phenomenon with similar forest diseases and declines in North America.

2 Characteristics of mal del cipres

The first visible symptom of mal del cipres in individual trees is chlorotic foliage. Trees may die rapidly, in which case foliage changes from chlorotic to red. Based on increment cores from symptomatic trees, however, radial growth decline may occur for 75 years before tree mortality (S. Cali 1995, personal communication, Centro Regional Universidad Bariloche, San Carlos de Bariloche, Argentina). In this case, crown symptoms progress as follows: chlorosis, gradual defoliation (Fig. 2) until only one living branch remains, complete defoliation and, finally, tree mortality (Fig. 3). Trees of all sizes are affected (Havrylenko et al. 1989).

Removal of soil from the root collar and major roots and examination of root surfaces and subcortical tissues commonly is used to detect and identify root diseases. Visible fungal mycelium is common with some North American root diseases caused by *Armillaria ostoyae* (Romang.) Herink, *Phellinus weirii* (Murr.) Gilb., or *Heterobasidion annosum* (Fr.) Bref. (Hansen and Lewis 1997), but roots and root collars of trees affected by mal del cipres show no visible fungal mycelium either ectotrophically or subcortically. Instead, necrotic tissue adjacent to clear wood is usually present at the root collar of trees with advanced crown symptoms. These symptoms resemble a root disease caused by *Phytophthora lateralis* Tucker and Milbrath on Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) in coastal Oregon and California (Roth et al. 1987). Additional support that mal del cipres may be caused by pathogenic root fungi comes from spatial segregation studies suggesting that tree mortality tends to be patchy (Rosso et al. 1989, 1994). Roots of chlorotic trees are

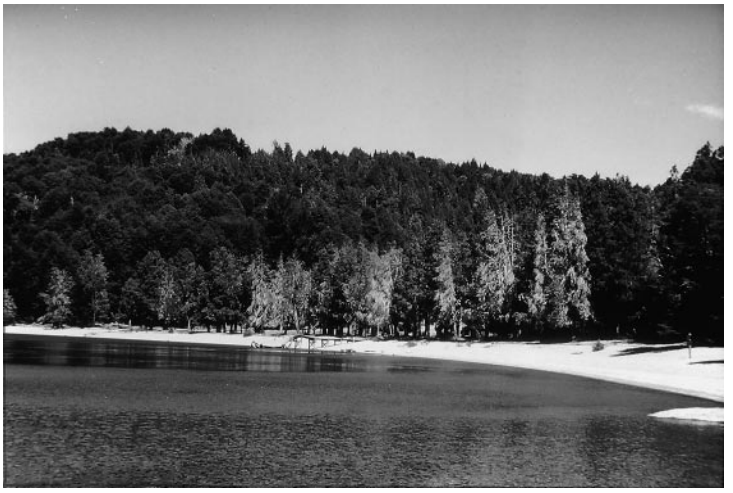

Fig. 1. Mal del cipres occurs in pristine forests in the Patagonian Andes, primarily in poorly drained areas as shown here near Nahuel Haupi Lake, Argentina

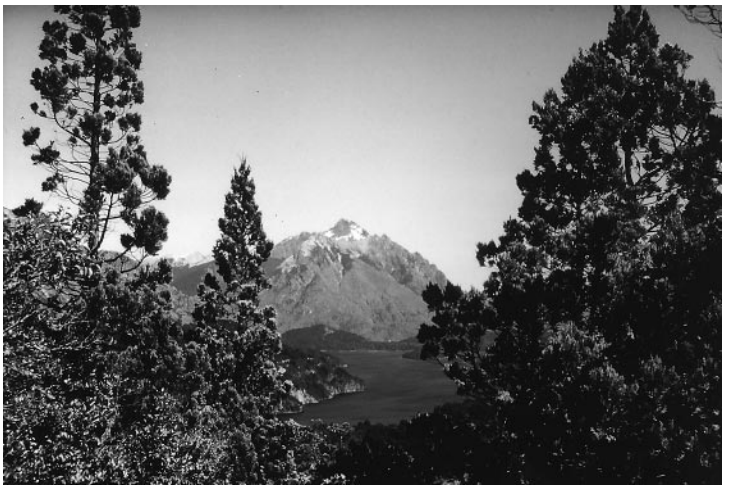

Fig. 2. Trees affected by mal del cipres are gradually defoliated as seen in the cypress on the left as contrasted to a healthy cypress on the right near Nahual Haupi Lake

Fig. 3. Trees affected by mal del cipres eventually may die after an extended period of decline as in this affected 90–140-year-old cypress stand on Victoria Island, Nahuel Haupi Lake

often necrotic and stained. Roots of partially or completely dead trees show either a brown-cubical rot or a white-stringy rot (RAJCHENBERG et al. 1998). It is not known whether the decay-causing fungi are primary or secondary invaders.

Increment cores from affected Cordilleran cypress often show a rapid acceleration of stem radial growth, followed by either a rapid decline or a prolonged period (>50 years) of slow (>10 rings/mm) radial growth before tree death (S. CALI 1995, personal communication, Centro Regional Universidad Bariloche, San Carlos de Bariloche, Argentina). This accelerated growth is interpreted to be a response of the still-living side of the tree to

compensate for the dead side. Eventually, however, radial growth rapidly declines, presumably when roots supporting the living side of the tree are also affected and die.

Mal del cipres appears to be associated with areas of poor drainage and areas of higher precipitation (HAVRYLENKO et al. 1989; RAJCHENBERG et al. 1998). Cordilleran cypress growing in the mesic *Nothofagus* forests, where annual precipitation ranges from 160 to 180 cm, are affected by mal del cipres, while trees growing in the more xeric forests, where annual precipitation is 80–90 cm, do not exhibit an unusually high level of mortality.

3 Similar forest diseases and declines in North America

The water moulds (*Phytophthora* spp.) are destructive forest pathogens in North America, Asia, Australia, and Europe. *Phytophthora* root disease is especially damaging in poorly drained soils where excessive moisture aids in the dispersal of the zoospores (TRIONE 1959). The disease in Oregon and California is often associated with recent forest road construction and harvesting activities that foster movement of chlamydospores in transported soil. Port-Orford-cedar root disease in coastal Oregon and California is caused by an exotic pathogen, *P. lateralis*, believed to be introduced initially on nursery stock (ROTH et al. 1957). The native location and host(s) for the fungus are unknown.

Mortality of Alaska yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) is the most spectacular forest decline in south-east Alaska, affecting over 200 000 ha of unmanaged forest (SHAW et al. 1985, HENNON and SHAW 1994, 1997). Alaska yellow-cedar decline appears to affect radial growth of host trees for several decades before tree mortality and is associated with wet, poorly drained sites (HENNON et al. 1990c) as is true for mal del cipres (Table 1). After rigorous experimentation, researchers do not believe that biotic agents are the cause of Alaska yellow-cedar decline (HENNON 1990; HENNON et al. 1990a,b). Instead, a warming climate, which coincided with extensive tree mortality about 100 years ago, may have triggered one of the possible abiotic causes, such as freezing damage or soil toxicity (HENNON and SHAW 1994, 1997).

4 Hypotheses concerning mal del cipres

Researchers in Argentina agree that mal del cipres appears to be associated with wet soils and that death of individual trees may take several decades. The wet-soil hypothesis has not been rigorously tested, but it is supported by observations and data throughout Patagonia (HAVRYLENKO et al. 1989; RAJCHENBERG et al. 1998). The slow-death hypothesis is supported by observations of stem increment cores and root cross sections of symptomatic and asymptomatic trees (S. CALI 1995, personal communication, Centro Regional Universidad Bariloche, San Carlos de Bariloche, Argentina).

At least three hypotheses address the possible biotic causes of mal del cipres. One hypothesis states that the disease may be caused by an introduced pathogenic fungus, most probably a species of *Phytophthora*. Mal del cipres was first observed in 1948 on Victoria Island in Nahuel Haupi National Park, which was planted with exotic trees from around the world. Seedlings from Victoria Island were subsequently transplanted throughout Argentina, which could have facilitated disease spread (M. HAVRYLENKO 1995, personal communication, Centro Regional Universidad Bariloche, San Carlos de Bariloche, Argentina). Tree mortality appears to have spread across entire landscapes very rapidly, which suggests that a hypothetical pathogen may have been introduced.

Observations of stem and root cross-sections, however, suggest that Cordilleran cypress may be affected for over 75 years before they die. In contrast, trees affected by Port-Orford-cedar root disease die within a few years of infection (ROTH et al. 1957). If *Phytophthora* spp. are involved in mal del cipres, then they appear to be acting as weak pathogens

and certainly not as aggressive pathogens typical of introduced fungi. *Pythium* spp. and *Phytophthora* spp. have been isolated from soil and roots of both affected and apparently healthy cypress (RAJCHENBERG et al. 1998) as they were in healthy and affected stands of Alaska yellow-cedar (HANSEN et al. 1988).

An alternative hypothesis regarding biotic causes suggests that mal del cipres is caused by one or more species of basidiomycete fungi. One or two types of root decay are consistently associated with dead and dying cypress including a root decay associated with *Postia dissecta* (Lev.) Rajchenb. (RAJCHENBERG et al. 1998). GILBERTSON and RYVARDEN (1987), however, consider *Postia* to be an illegitimate name for *Oligoporus*. A species of decay fungus in Oregon and California, *Oligoporus amarus* (Hedgc.) Gilbn. and Ryv., causes a brown-cubical pocket rot of the heartwood of living incense-cedar (GILBERTSON and RYVARDEN 1987). Cordilleran cypress was formerly classified under the same genus as incense-cedar, *Libocedrus*. Widespread mortality similar to mal del cipres have not been observed, to date, in incense-cedar.

Another hypothesis is that mal del cipres may be associated with the lack or dysfunction of mycorrhizae of fine roots of Cordilleran cypress. A similar hypothesis was tested concerning Alaska yellow-cedar decline, but the lack or dysfunction of beneficial mycorrhizae did not appear to contribute to this decline, since vesicular-arbuscular mycorrhizae were common in cortical cells of live fine roots on both declining and healthy trees (HENNON et al. 1990b). Similar research is being proposed for mal del cipres.

As hypothesized for Alaska yellow-cedar decline (HENNON and SHAW 1994, 1997), mal del cipres may be associated with global warming. When more precipitation occurs as rain than as snow, water tables rise and roots that are normally insulated with snow may freeze during winter. Changes in temperature and form of precipitation may also affect decomposition processes, perhaps resulting in compounds toxic to cypress roots, as hypothesized for Alaska yellow-cedar. This hypothesis does not explain why Cordilleran cypress may be affected by the changing water table, but associated species are not.

The cohort senescence hypothesis described by MUELLER-DOMBOIS et al. (1983) proposes that vegetation regenerates as a result of some disturbance, develops as an even-aged cohort, and declines and dies synchronously. The cohort senescence hypothesis for mal del cipres is possible in that the shade-intolerant Cordilleran cypress often regenerates after disturbance (VEBLEN et al. 1992). Following stand-destroying fires, Cordilleran cypress and the associated southern beech (*Nothofagus dombeyi* (Mirb.) Oerst.) become established abundantly and develop into either single- or mixed-species stands of even-aged cohorts. Windthrow

Table 1. **Comparison of mal del cipres in Patagonia to yellow-cedar decline in Alaska and Port-Orford-cedar root disease in Oregon and California**

	Alaska yellow-cedar decline	Port-Orford-cedar root disease	Mal del cipres
Year first noticed	1909[1]	1952	1948
Species affected	*Chamaecyparis nootkatensis*	*Chamaecyparis lawsoniana*	*Austrocedrus chilensis*
Tree death	Rapid or slow: (3–140 years)	Rapid: (1–5 years)	Rapid or slow: (3–75 years)
Slow growth before death	50–60 years of >10 rings/mm	None	75+ years of >10 rings/mm
Cause	Unknown	*Phytophthora lateralis*	Unknown

[1] Noticed at this time on 'old' dead trees. Work of HENNON and SHAW (1994, 1997) suggests an onset around 1880.

and earthquakes, common in the Patagonian Andes, create fine and coarse gaps that also favour the establishment of southern beech and Cordilleran cypress. Areas that contain an even-aged cohort would then experience synchronous mortality. This hypothesis, however, does not explain the actual cause(s) of tree mortality or account for individual tree mortality or for mortality throughout uneven-aged stands. In mixed-species cohorts, only Cordilleran cypress is affected by mal del cipres.

The decline syndrome hypothesis, with predisposing, inciting and contributing factors as described by HOUSTON (1981) and MANION (1991), may best describe mal del cipres because multiple factors could contribute to the phenomenon. Predisposing factors for mal del cipres may include changes in water tables or drainage patterns resulting from climate change or human activities. Inciting factors have not been hypothesized but may include drought or frost damage. Contributing factors may include biotic agents such as the root decaying fungi. Most of these factors have been identified with mal del cipres, and no single factor may adequately explain the decline in Cordilleran cypress in Patagonia. The deterioration of Alaska yellow-cedar has been described as a naturally occurring forest decline (HENNON and SHAW 1994, 1997). Mal del cipres in Patagonia resembles yellow-cedar decline in Alaska more closely than it resembles Port-Orford-cedar root disease in Oregon and California (Table 1). Therefore, the possibility that mal del cipres is a decline syndrome should be explored.

5 Current and future research

Numerous research topics are being pursued and discussed in Patagonian ecosystems concerning mal del cipres. The most important pathology studies being conducted are to determine the role of suspected causal microorganisms. Trees are being identified within several crown symptom classes, root systems are being totally excavated, condition of the primary roots and decay extent are being recorded, and associated microorganisms are being identified.

In conjunction with root excavations, dendrochronological studies are being conducted on stems and roots of sampled trees. Growth measurements are being correlated with root and root collar condition.

Studies to determine the cause of mal del cipres are being conducted using suspected causal microorganisms singly and in combination to artificially inoculate seedlings and test Koch's postulates for pathogenicity. Water relations studies could be conducted simultaneously.

As with Alaska yellow-cedar decline (HENNON and SHAW 1994, 1997), research on possible abiotic factors, such as freezing of fine roots and soil toxicity, and their link to climatic change could be pursued.

Future studies could assess the geographical occurrence of mal del cipres through time. Data can be gathered by satellite imagery, aerial photography, or ground-based surveys conducted on a regional scale along the entire range of Cordilleran cypress in Patagonia.

In conclusion, research is being conducted to explore the cause of mal del cipres, which is hypothesized to be associated with dysfunctional root systems. The relationships between above- and below-ground symptoms and associated microorganisms need to be understood in order to determine the cause of the mortality. Once cause is determined, then Cordilleran cypress may be effectively managed for commercial and aesthetic purposes in the Patagonian Andes.

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Résumé

La mortalité du Cyprès (mal del cipres) dans les Andes de Patagonie : comparaison avec des maladies forestières semblables et des dépérissements d'Amérique du nord

La mortalité générale d'*Austrocedrus chilensis* a lieu dans les forêts naturelles et artificielles du sud-ouest de l'Argentine et peut-être du sud-est du Chili. Les arbres affectés peuvent mourir rapidement mais la mortalité est généralement précédée durant plusieurs décades, par une croissance radiale très réduite au niveau du tronc. Les racines sont souvent affectées par un ou plusieurs types d'altérations. La mortalité du cyprès, appelée localement 'mal del cipres', est comparable à une grave maladie d'Amérique du nord, la maladie racinaire du *Chamaecyparis lawsoniana* en Oregon et Californie, et à un grave dépérissement, celui du *Chamaecyparis nootkatensis* du sud est de l'Alaska. L'article discute plusieurs hypothèses concernant le 'mal del cipres' et compare la recherche actuelle sur le dépérissement forestier, en Patagonie et en Amérique du nord.

Zusammenfassung

Das 'Zypressensterben' (mal del cipres) in den Patagonischen Anden: Vergleiche mit ähnlichen Komplexkrankheiten in Nordamerika

In den Primärwäldern und Forsten Südwest-Argentiniens und möglicherweise auch in Südost-Chile ist das Absterben der Kordillierenzypresse (*Austrocedrus chilensis*) ein verbreitetes Phänomen. Die betroffenen Bäume sterben rasch ab; vorher ist jedoch in der Regel ein über mehrere Jahrzehnte sehr stark reduzierter Radialzuwachs nachweisbar. Die Wurzeln zeigen oft einen oder mehrere Fäuletypen. Dieses Baumsterben, das im Verbreitungsgebiet als 'mal del cipres' bezeichnet wird, zeigt Ähnlichkeiten zu einer bedeutenden Baumkrankheit in Nord-Amerika, der *Chamaecyparis lawsoniana* -Wurzelfäule in Oregon und Kalifornien, sowie zu einem verbreiteten Baumsterben bei *Chamaecyparis nootkatensis* in Südost-Alaska. Der vorliegende Beitrag diskutiert verschiedene Hypothesen zu den Ursachen des 'Zypressensterbens' und vergleicht die aktuellen Forschungsansätze zu diesem Problem in Patagonien und Nordamerika.

References

BURNS, R. M.; HONKALA, B. H., (eds), 1990: Silvics of North America, Vol. 1. Conifers. Agricultural Handbook No. 654. Washington, DC: USDA Forest Service, 173–180.

GILBERTSON, R. L.; RYVARDEN, L., 1987: North American Polypores, Vol. 2. Oslo, Norway: Fungiflora.

HANSEN, E. M.; LEWIS, K. J., 1997: Compendium of conifer diseases. St. Paul, MN: The American Phytopathological Society Press. 101 pp.

–; HAMM, P. B.; SHAW, C. G. III; HENNON, P. E., 1988: *Phytophthora drechsleri* in remote areas of southeast Alaska. Trans. Brit. Mycol. Soc. **91,** 379–388.

HAVRYLENKO, M.; ROSSO, P. H. A.; FONTENLA, S. B., 1989: *Austrocedrus chilensis*: contribucion al estudio de su mortalidad en Argentina (English summary). Bosque **10,** 29–36.

HENNON, P. E., 1990: Fungi on *Chamaecyparis nootkatensis*. Mycologia **82,** 59–66.

–; SHAW, C. G. III, 1994: Did climatic warming trigger the onset and development of yellow-cedar decline in southeast Alaska? Eur. J. For. Path. **24,** 399–418.

–; –, 1997: The enigma of yellow-cedar decline: what is killing these long-lived, defensive trees? J. For. **95,** 4–10.

–; HANSEN, E. M.; SHAW, C. G. III, 1990a: Dynamics of decline and mortality in *Chamaecyparis nootkatensis* in southeast Alaska. Can. J. Bot. **68,** 651–662.

–; –; –, 1990b: Symptoms and fungal associations of declining *Chamaecyparis nootkatensis* in southeast Alaska. Plant Dis. **74,** 267–273.

–; –; –, 1990c: Dating decline and mortality of *Chamaecyparis nootkatensis* in southeast Alaska. For. Sci. **36,** 502–515.

HOUSTON, D. R., 1981: Stress triggered tree diseases: the diebacks and declines. NE-INF-41–81. Bromall, PA: USDA Forest Service Northeastern For. Exp. Stn., 36 pp.

MANION, P. D., 1991: Tree Disease Concepts, 2nd edn. Englewood Cliffs, NJ: Prentice-Hall, 402 pp.

MUELLER-DOMBOIS, D.; CANFIELD, J. E.; HOLT, R. A.; BUELOW, G. P., 1983: Tree-group death in North American and Hawaiian forests: a pathological problem or a new problem for vegetation ecology? Phytocoenologia **11,** 117–137.

RAJCHENBERG, M.; BARROETAVENA, C.; CWIELONG, P. P.; ROSSINI, M.; CABRAL, D.; SIVORI, A., 1998: Fungal species associated with the decline of *Austrocedrus chilensis* in Patagonia, Argentina: preliminary results. In: Root and Butt Rots of Forest Trees (9th Int. Conf. Root and Butt Rots, Carcans-Maubuisson, Sept. 1–7, 1997). Ed. by DELATOUR, C.; GUILLAUMIN, J. J.; LUNG-ESCARMANT, B.; MARÇAIS, B. (France), Les Colloques no 89, 235–244. INRA Editions.

ROSSO, P. H.; HAVRYLENKO, M.; FONTENLA, S. B., 1989: *Austrocedrus chilensis*: asociacion espacial entre individuos sanos y afectados por la mortalidad (English summary). Bosque **10,** 85–88.

–; BACCALA, N.; HAVRYLENKO, M.; FONTENLA, S., 1994: Spatial pattern of *Austrocedrus chilensis* wilting and the scope of autocorrelation analysis in natural forests. For. Ecol. Management **67,** 273–279.

ROTH, L. F.; TRIONE, E. J.; RUHMANN, W. H., 1957: Phytophthora-induced root rot of native Port-Orford-cedar. J. For. **55,** 294–298.

–; HARVEY, R. D. JR; KLIEJUNAS, J. T., 1987: Port-Orford-cedar root disease. R6 FPM-PR-294–87. Portland, OR: USDA Forest Service Pac. Northwest Reg., 11 pp.

SHAW, C. G. III; EGLITIS, A.; LAURENT, T. H.; HENNON, P. E., 1985: Decline and mortality of *Chamaecyparis nootkatensis* in southeastern Alaska, a problem of long duration but unknown cause. Plant Dis. **69,** 13–17.

TRIONE, E. J., 1959: The pathology of *Phytophthora lateralis* on native *Chamaecyparis lawsoniana*. Phytopathology **49,** 306–310.

VEBLEN, T. T.; KITZBERGER, T.; LARA, A., 1992: Disturbance and forest dynamics along a transect from Andean rain forest to Patagonian shrubland. J. Veg. Sci. **3,** 507–520.

–; BURNS, B. R.; KITZBERGER, T.; LARA, A.; VILLALBA, R., 1995: The ecology of the conifers of southern South America. In: The Ecology of Southern Conifers. Ed. by ENRIGHT, N. J.; HILL, R. S. Carlton, Victoria, Australia: Melbourne University Press. pp. 120–321.