The Conservation of *Fitzroya cupressoides* and Its Environment in Southern Chile

by

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INTRODUCTION

Fitzroya cupressoides (Mol.) Johnston, or 'Alerce' *, is a giant conifer occurring mainly in southern Chile but also in southwestern Argentina, whose continued existence in large numbers is threatened by both cultural and ecological factors. Although not nearly as large as *Sequoiadendron giganteum* (Lindl.) Buchh., the physiognomy of Alerce is reminiscent of that of this 'Big Tree' of California, and its wood is as highly valued as that of *Sequoia sempervirens* (Lamb.) Endl. (Coast Redwood). Alerce has long been the most highly-valued timber in Chile, and consequently only small remnants persist of the once extensive forests of this largest and longest-lived tree of all Chile. Most of the Alerce stands remaining in Argentina are now protected, due to their location in national parks. However, by far the greater concentration of Alerce has always been on the Chilean side of the Andes, where its exploitation continues on a large scale. The eventual demise of Alerce was predicted as early as the late nineteenth century by Fonck (1896), and recently interest in conserving this species has become intense (Elizalde, 1970; Ramírez & Riveros, 1975: Stutzin, 1975). The problems associated with the preservation of Alerce and its unique environment in southern Chile, which are discussed in this paper, illustrate some of the dilemmas encountered in conservation efforts in underdeveloped countries.

Attaining heights of over 50 metres, Alerce is one of Chile's tallest trees, and with trunk diameters in excess of 4 m it is by volume the largest tree of the southern cone of South America (Urban, 1934; Muñoz, 1971). Of the largest individuals only gigantic stumps remain, such as the 'Silla del Presidente' at Estación Alerce near Puerto Montt (Fig. 1), which measures 4 m across. There are historical accounts of Alerce over 5 m in diameter at breast height and well over 60 m high (Fonck, 1896). Alerce is one of the longest-lived trees in South America, with reported annual growth-ring counts of over 2,000 years and estimated ages of over 3,000 years (Schmithüsen, 1960; Muñoz, 1971). The reddish-brown bark of Alerce is very fibrous, much as is that of *Sequoia sempervirens*, and reaches thicknesses of up to 5 cm. On old trees, branches are relatively short and concentrated in the upper one-fourth of the trunk, forming a crown of somewhat pyramidal shape (Fig. 2). Alerce belongs to the subfamily Callitroideae of the Cupressaceae, and its closest relative is *Diselma archeri* Hook., of Tasmania (DeLaubenfels, 1965).

* Pronounced 'ah-laír-say'.—Ed.

DISTRIBUTION AND HABITATS

Alerce occurs discontinuously, from approximately lat. 39°50′ to 43°30′ S in Chile and southwestern Argentina, in two disjunct habitat types: (1) poorly-drained lowlands, and (2) at altitudes ranging from 700 m to near timber-line at over 1,000 m. It is also found occasionally in small numbers at intermediate altitudes. Originally, small forests of Alerce were numerous in the area ranging from Cerro San Ramón (just north of Valdivia) southwards to around Lakes Llanquihue, Todos Los Santos, Puyehue, and Nahuel Huapi—near the upper forest limits in the Andes (Juliet, 1872; Urban, 1934). They continued southwards along the Seno de Reloncaví to Río Corcovado (43°16′ S), and to 43°30′ S just north of the Río Palena (Fonck, 1896; Reiche, 1934). Extensive Alerce forests occurred in the Coastal Cordillera, from 40°00′ S just south of Valdivia to 41°15′ S, and smaller forests were found on the island of Chiloé (Fonck, 1896; Reiche, 1934)—cf. Fig. 1.

Physiographically, this region can be divided into the Coastal Cordillera, the Central Depression, and the Andean Cordillera. The oldest rocks in the region are found in the Coastal Cordillera, which are made up of Palaeozoic and Precambrian metamorphic rocks and are relatively low, exceeding 1,000 m in only a few places (Ruíz *et al.*, 1966; Illies, 1970). The uplands of western Chiloé Island are an extension of the Coastal Cordillera, but here the maximum altitudes

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FIG. 1. *Sketch-map of south-central Chile.*

are 700 to 800 m. The Central Depression is a structural depression, or *graben*, filled with Quaternary glacial, fluvio-glacial, aeolian, and alluvial, deposits and volcanic ash. It has a maximum altitude of less than 200 m and gradually becomes lower towards the south. The Andes at these latitudes constitute a broad mountainous zone from 60 to 100 km in width, divided into a labyrinth of heights and valleys. The Andes, which are still uplifting, were extensively glaciated during the Pleistocene, but most of the glaciated surfaces have been covered by extensive Recent andesitic volcanic deposits. The summits of the Andes in this region average about 2,000 m, with only a few peaks exceeding 2,300 m.

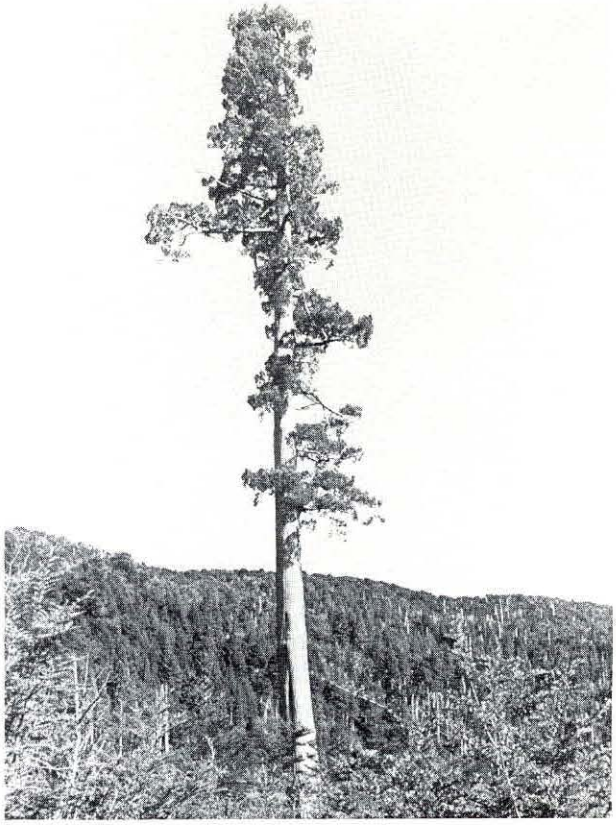

FIG. 2. *Isolated Alerce in the foreground and Alerce forests in the centre-background at approximately 1,000 m, Cordillera Pelada, Chile. Photo: F. Schlegel.*

The climate of Chile, from approximately lat. 39° 00′ to 43° 30′ S, is a west-coast maritime climate characterized by a mild temperature-range and high annual precipitation; although the summer months (Jan.–March) are clearly drier than the rest of the year, none of the weather stations record averages of less than 100 mm for the whole summer. In the southern part of this region (south of 41° 00′ S), the climate remains very moist all the year around, with average monthly precipitation exceeding 100 mm even during the driest summer month. Within this region there is, of course, a great deal of local variation in the climatic regime. Most of the stations in this part of Chile for which temperature data are available show ranges of less than 9°C in the mean monthly temperatures and relatively high winter temperatures for these latitudes (Table I). This mildness of temperature regime is due to the strong oceanic influence and the relative unimportance of continental air-masses. The northern part of this region—the Chilean Lake District—according to the Koeppen classification is an oceanic west-coast climate with a Mediterranean influence (Cfsb), and borders on the zone of warm temperate climate to the north (Thomasson, 1963).

Most of the range of Alerce is south of the Lake District, which itself lies in a zone of cold-temperate maritime climate (Cfb). Throughout the area of west coast maritime climate there is a tendency towards increasing annual precipitation and decreasing severity of the summer dry season from north to south (cf. Table I).

TABLE I

Mean Monthly Temperatures and Precipitation. Data from Ljungner (1939), Almeyda & Saez (1958), Thomasson (1963), Anon. (1964), Fuenzalida (1966), Montaldo (1966), and Huber (1970).

Locality	*Altitude (m)*	*Mean temperatures (°C)*		*Annual rainfall (mm)*
		January (mean)	*July (mean)*	
Valdivia 39° 48′ S, 73° 14′ W	9	16.9	7.6	2,472
Punta Galera 40° 02′ S, 73° 44′ W	40	13.7	9.0	2,105
La Unión 40° 15′ S, 73° 02′ W	35	—	—	1,267
Río Bueno 40° 18′ S, 72° 55′ W	58	16.4	6.9	1,235
Osorno 40° 33′ S, 73° 09′ W	24	—	—	1,328
Antillanca 40° 46′ S, 72° 12′ W	1,060	—	—	5,633
Peulla 41° 07′ S, 72° 03′ W	190	—	—	3,377
Bariloche 41° 09′ S, 71° 17′ W	786	—	—	1,009
Puerto Montt 41° 28′ S, 72° 56′ W	13	14.9	7.7	1,840
Punta Corona 41° 47′ S, 73° 52′ W	48	13.8	8.3	2,425
Castro 42° 29′ S, 73° 45′ W	30	14.5	7.6	1,978
Reñihue 42° 35′ S, 72° 35′ W	20	—	—	5,387
Isla Guafa 43° 34′ S, 74° 45′ W	140	12.4	7.5	1,403
Melinka 43° 54′ S, 73° 46′ W	5	13.3	7.6	3,174

Similarly, the east-facing slopes and the Central Depression are zones of less precipitation than most other areas as a consequence of the rain-shadow effects of the Coastal and Andean Cordilleras on the moist Pacific air-masses coming from the west. The greatest precipitation probably occurs at high altitudes on the Pacific side of the Coastal Cordillera, where meteorological stations are absent; however, short-term measurements made at 1,000 m near the summit of this range recorded 756 mm from December through February, which are generally three of the driest months of the year (Weinberger, 1973). On the western slopes of the Andes, the annual precipitation commonly exceeds 4,000 mm, while at altitudes above 700 m much of the winter precipitation is in the form of snow. Within this region of humid climate, Alerce is found in the wettest areas—where soils are poorly drained or where the precipitation exceeds 3,000 mm (Bonnemann, 1973).

In the Coastal Cordillera, which are known as the Cordillera Pelada between Valdivia and Chiloé, Alerce is found at altitudes of approximately 700 to over 1,000 m—at the upper altitudes as the dominant of extensive areas of forest, most of which has now been burned and cut. This zone was visited by the present authors in December 1975, examples of the vegetation at Altos del Mirador (40° 10′ S) having been described in detail by Ramírez & Riveros (1975). Here, on thin and acid podzolic soils, Alerce forms a canopy at a height of 30 to 40 m, with an intermediate tree-layer formed by *Nothofagus betuloides* (Mirb.) Oerst. and *Drimys winteri* Forst. at a height of 15 to 20 m. The shrub layer reaches heights of up to 2 m and is dominated by the bamboo *Chusquea nigricans* Phil., *Desfontainea spinosa* Ruíz & Pav., *Berberis serrato-dentata* Lech., and *Ugni candollei* (Barn.) Berg. The herbaceous layer is very sparse and formed primarily by the cushion sedge *Oreobolus obtusangulus* Gaud. and the fern *Blechnum magellanicum* (Desv.) Mett. Where drainage is extremely poor, a bog vegetation prevails which consists mainly of *O. obtusangulus*, *Donatia fascicularis* Forst., *Dacrydium fonckii* (Phil.) Flor., *Myrteola barneoudii* Berg., *Gentiana factea* Phil., *Tapeinia magellanica* (Lam.) Juss., *Drosera uniflora* Willd., and *Gaimardia australis* Gaud. Often found in the transitional areas between the Alerce forests and the bogs is *Pilgerodendron uvifera* (D.Don) Flor., a conifer similar to Alerce but not reaching as great a size. Phytogeographically, this assemblage of plants near the summits of the Cordillera Pelada represents the northernmost outlier of the subantarctic vegetation of southern Chile (Reiche, 1934).

The largest area of Alerce forest remaining in the Andes occurs in the region that ranges from 40° 30′ to 42° 00′ S. The vegetation of the southern part of this region, surrounding Volcán Apagado, was studied in November 1975 on an extensive property known as Contao, where Alerce is currently being exploited on a large scale. Here, Alerce forests are developed on thin (20–80 cm deep) soils derived mostly from volcanic ash overlying fluvio-glacial deposits and metamorphic rocks. The surface horizon (0–15 cm) of these soils is very acidic (*p*H 3.7 to 4.1) and rich in organic matter resulting in high C/N ratios (20 to 50). The high precipitation and poor permeability of some of the soils' parent materials result in poor drainage on many sites which is reflected in blue-grey mottling. Under these conditions, iron compounds are reduced and leached to the zone of contact with the parent material, where they are precipitated as a thin layer of iron oxide.

Alerce commonly forms a canopy at 35 to 40 m, with *Nothofagus betuloides*, *Pilgerodendron uvifera*, and *Podocarpus nubigenus* Lindl., forming an intermediate tree layer 5 to 10 m lower. In the stands that remain, Alerce accounts for two-thirds of the basal area, but local informants indicated that in the exploited forests it had had substantially higher basal areas before exploitation. The open shrub layer is dominated by *Chusquea nigricans*, *Drimys winteri* var. *andina* Reiche, *Desfontainea spinosa*, *Philesia magellanica* Gmel., *Maytenus magellanica* (Lam.) Hook. f., *Pernettya* spp., and *Berberis* sp. The herb layer is very sparse and consists mostly of the ferns *Blechnum magellanicum* and *Gleichenia squamulosa* (Desv.) Moore, together with abundant bryophytes. Below the altitude at which Alerce dominates the forest (approximately 700 m), it occurs as isolated individuals in forests dominated by *Nothofagus nitida* (Phil.) Krasser, *Drimys winteri*, *Laurelia philippiana* Looser, and *Podocarpus nubigenus*. On the slopes of Volcán Apagado, Alerce forms the tree-line on the bare scoria (gravel-sized pyroclastic ejecta); elsewhere, *Nothofagus* spp. occurred above the highest Alerce.

In its lowland habitat, particularly in the area between Puerto Montt and Lago Llanquihue, Alerce has been almost entirely eliminated. In the nineteenth century a 25 by 3 km Alerce forest extended from Puerto Montt to Puerto Varas, the centre of which was named Estación Alerce (Domeyko, 1850; Reiche, 1934; Urban, 1934). Here Alerce forests were found on soils derived from volcanic ash in which iron and silica hard-pans had formed in the underlying glacial gravels, resulting in a high water-table and waterlogged conditions nearly year-around (Wright, 1959–60). Alerce formed pure as well as mixed stands with small trees such as *Tepualia stipularis* (Hook. & Arn.) Griseb., *Drimys winteri*, *Gevuina avellana* Mol., and *Embothrium coccineum* Forst. The common shrubs were *Desfontainea spinosa* and *Baccharis sphaerocephala* Hook. & Arn., and among the plants of the ground-layer were species of *Sphagnum*, *Oreobolus*, *Carpha*, *Pernettya*, and small Gramineae (Reiche, 1934).

HISTORY OF EXPLOITATION

Alerce wood is highly prized because of its remarkable durability and resistance to fungal and insect attack. Cases of Alerce logs lying on the soil for over 200 years and yet showing almost no signs of decay, are common (Bonnemann, 1973). Schmithüsen (1960) witnessed the excavation in a road-building operation of an Alerce log which had been buried for at least 2,000 years but whose wood was still suitable for saw-timber. Similarly, Alerce wood that had been used in the construction of buildings in the seventeenth century still shows very little weathering—despite the extremely moist climate of southern Chile. This extraordinary durability as well as the aesthetic appeal of the reddish-brown Alerce wood has placed it in high demand for a wide variety of products from the sixteenth century onwards.

As early as 1599, the exploitation of Alerce achieved great commercial importance on the island of Chiloé and in the area bordering the Seno de Reloncaví (Fonck, 1896). Estero de Comau (42° 20′ S), on the coast of the mainland opposite Chiloé Island, was a major centre of Alerce cutting from the seventeenth through the nineteenth centuries. Exploitation of the Alerce forests of Calbuco and Huar, a few kilometres south of the present-day location of Puerto Montt (Fig. 1), became important later in the Spanish Colonial period; the timber from these sites was transported *via* the Seno de Reloncaví to the shipyards at Melipulli near Puerto Montt. The rigours of working in the dark Alerce forests, and of transporting the timber over the muddy tracks during the colonial period, have been described by Fonck (1896). In the nineteenth century in southern Chile, to say that a young man had felled an Alerce meant that he had reached adulthood. In the seventeenth century, Alerce wood was one of the most important products of the Chilean colony; Alerce boards were even used as media of exchange and as the standard against which the value of other items was determined (Reiche, 1934).

This early exploitation nearly eliminated Alerce from all accessible sites by the end of the nineteenth century. As early as the 1850s, much of the huge Alerce forest north of Puerto Montt had been cut, and by the 1890s only a few trees remained (Fonck, 1896; Pérez, 1958). Much of the Alerce forest near the summit of the Cordillera Pelada to the south of Valdivia had already been cut and burned over by the mid-nineteenth century (Philippi, 1865). The clearing and burning associated with the colonization of southern Chile from Valdivia to Puerto Montt was one of the most massive and rapid deforestations ever recorded in Latin America (Cunill, 1974). In the mid-nineteenth century, over 6,000 m^3 of Alerce wood was being exported to northern and central Chile and to Europe each year, making it the principal source of income of southern Chile (Bonnemann, 1973).

CURRENT STATUS

The commercial importance of Alerce is still substantial in Chile. During the 1960s it accounted for approximately 6% by value of Chile's total lumber production and 11% by value of lumber exports (Bonnemann, 1973). The wood of Alerce has a relatively low specific gravity (0.42 gr/cm^3 at 12% humidity) and mechanical resistance; thus, it is not suitable for structural uses. However, due to its remarkable durability, resistance to biotic attack, and dimensional stability, it has been widely used for boat construction, musical instruments (violins, guitars, and pianos), veneer, window frames, doors, shutters, roof shingles, and, formerly, telephone poles.

In 1969, legislation was enacted in Chile which purportedly provided some degree of protection for Alerce. According to this law, a management plan must be approved by the national forestry authorities prior to the cutting of Alerce, and measures must be taken to assure 'repopulation' of the forest (Corporación Nacional Forestal, 1974). Although the law may have restricted the cutting of Alerce to some extent, it did not afford it the degree of protection which frequently is erroneously assumed by the Chilean public, and more recent forestry legislation requiring management plans for all types of exploitations indicates that the special protection for Alerce is only minimal. More encouraging is the probable expansion of Los Alerzales National Park in the Cordillera Pelada. However, the exploitation of Alerce continues in Chile illegally on a small scale—even occasionally in national parks (Putney, 1970; Wetterberg, 1971)—and legally on a large scale.

Today, the most important centres of Alerce exploitation remaining in Chile include the Cordillera Pelada (where trees are cut primarily for shingle production) and the large commercial operations bordering Lago Chapo on its south side and in the zone surrounding Volcán Apagado (Contao). The Contao operation was observed by us in November 1975; here the logging system used is high lead-cable logging, in which the logs are dragged out by huge motor-driven cables attached to a centrally-located tower. In Contao, former locations of the tower are marked by clear-felled areas several hundred metres in diameter. These clear-cuts overlap in many cases in such a manner that surfaces of several square kilometres are entirely deforested (Fig. 3). In comparative studies of logging systems in the U.S.A., cable-skidding (dragging of the logs by cable) has been shown to be

FIG. 3. *Clear-cut Alerce forests at approximately 800 m at Contao, Chile. The trees in the foreground with the pyramidal shape are Alerce; the species also dominates the forests on the lower slopes of snow-covered Volcán Apagado in the background. Photo: Dr J. E. Schlatter.*

by far the most destructive of soils and vegetation (Klock, 1975).

In an area such as Contao, with its very rugged topography and annual precipitation of over 3,000 mm, the potential for accelerated erosion is great. However, reconnaissance of the Contao area indicates relatively little gulleying and sedimentation in comparison with other areas of exploited native forest in southern Chile. While it may be that, due to the recency of cutting (mostly since 1966), the accelerated erosion is only in an incipient stage, the lack of obvious signs of erosion in such extensive areas of felled forest is remarkable. It is probably accounted for by the fact that only Alerce logs are removed from the exploitation site and, thus, one-third to one-half of the standing timber volume is left to decay on the ground. This cover of debris protects the soil from excessive erosion. Consequently, severe erosion is associated primarily with sites where Alerce logs have been repeatedly skidded over the same paths, with slopes greater than 25°, and with proximity to the inadequately-drained logging roads.

ECOLOGICAL ASPECTS OF PROTECTING ALERCE

The argument that Alerce is a rare tree of great scientific as well as cultural importance that should be given total protection is often met with the counter-argument that it is a 'relict species' which has lost its vigour and will gradually disappear as the result of natural processes. Consequently—according to the proponents of the continued cutting of Alerce—attempts to preserve it in its native habitat will fail in the long-run and, thus, its considerable economic value should be exploited immediately.

The belief that Alerce is a relict has its origin in (1) the fact that it is a conifer, (2) the type of habitat it occupies, and (3) its very poor regeneration following cutting. Like most other conifers, Alerce is believed to have been more widespread during the Tertiary period and, thus, its present distribution is a relict of a previously much more extensive one. However, it cannot be assumed simply on the basis of such range reduction that the natural extinction of Alerce is at all imminent. The second basis for ascribing relict status to Alerce is related to the fact that both its lowland and high-altitude habitats are sites of very harsh conditions under which few other Chilean trees prosper. At high altitudes, Alerce often grows on bare volcanic ash and scoria deposits or, at best, on very thin soils, while in the lowlands it grows on intermittently waterlogged pseudogleys or partially podzolized soils—both of which are considered 'relict habitats' to which Alerce is restricted as a consequence of its low competitive capacity (Schmithüsen, 1960). Moreover, as environmentally severe habitats will always exist, this is not a sound basis for predicting the natural demise of Alerce. Very poor regeneration of Alerce following cutting is widely reported by Chilean foresters. The implication is that under present climatic conditions Alerce has a much-reduced regenerative capacity which, if universally true, will greatly impede preservation efforts.

The degree to which Alerce does regenerate following exploitation was investigated in the Contao area, though limitations of time and inclement weather permitted the taking of only small samples of the vegetation and soils. Four sites, ranging in date of exploitation from 1967 to 1970, were sampled by systematically located 0.5 m^2 plots at 2-m intervals along several parallel 20 m transects spaced 5 m apart; these transects were located near the centres as well as along the borders of the exploited sites. In these 0.5 m^2 plots the percentage cover was estimated for all vascular plant species in the following categories: less than 1, 1–5, 6–25, 26–50, 51–75, and over 75%. Cover was also estimated for (1) bryophytes, (2) felled trunks, (3) leaves, litter, and branches, (4) stumps, and (5) bare mineral soil or exposed rock. The results of these samples of the vegetation on the exploited sites are summarized in Table II; average percentage cover for each species was calculated from the frequency of the mid-points of the cover classes recorded for that species in the 0.5 m^2 plots.

Only a single Alerce seedling was present in one of the sample plots, and no others were observed anywhere in the exploited areas. By far the most frequent and dominant species on the exploited sites was the bamboo *Chusquea nigricans*, which is also common in the understorey of the uncut Alerce forests. A substantial amount of *Podocarpus nubigenus* and *Nothofagus betuloides* regeneration was evident; these are the species that make up the intermediate tree layer in the near-by uncut Alerce forests. Thus, these data confirm the belief that Alerce regenerates extremely poorly following cutting, and suggest that the exploited forest would eventually be replaced by a forest dominated by *Podocarpus nubigenus* and *Nothofagus betuloides*.

There are several possible explanations of the observed lack of regeneration of Alerce since exploitation began in 1966 in the Contao area. The presence of huge quantities of debris from the clear-cuts may give rise to soil conditions that are inimical to the germination and establishment of Alerce seedlings—such as development of an unfavourable C/N ratio in the soil organic matter. To test this possibility, five soil samples were collected from the uppermost 15 cm of the soil profiles in one forest site and each of three exploited sites. The *p*Hs and percentages by weight of the carbon and nitrogen contents of these samples are presented in Table III. The only statistically significant difference between the two sets of samples is the higher *p*H of

TABLE II

Vegetation on Sites of Recently Clear-felled Fitzroya cupressoides *Forest.*
F = percentage of the quadrats in which a species was present (percentage quadrat frequency).
C = average percentage cover.

Year of clear-felling	*1967*		*1968*		*1969*		*1970*	
Altitude	910 m		860 m		825 m		750 m	
Slope	2°		20°		10°		23°	
Aspect	S70°W		S20°E		S30°W		S5°E	
Number of 0.5 m² plots	33		22		22		22	
	F	*C*	*F*	*C*	*F*	*C*	*F*	*C*
Trees								
Fitzroya cupressoides (Mol.) Johnston			4.5	0.1				
Podocarpus nubigenus Lindl.	27.3	2.6	13.6	0.8	4.5	0.7		
Nothofagus betuloides (Mirb.) Oerst.	6.1	0.5	27.3	0.7				
N. nitida (Phil.) Krasser			9.1	1.3				
Weinmannia trichosperma Cav.	3.1	0.2						
Lomatia ferruginea (Cav.) R. Br.							4.5	0.1
Shrubs								
Chusquea nigricans Phil.	97.0	24.2	100.0	35.4	95.5	35.5	100.0	25.7
Myrceugenia chrysocarpa (Berg.) Kaus.	6.1	0.2			4.5	0.1	36.4	2.3
Pernettya poeppigii (DC.) Klotzch	48.5	1.1	72.7	2.3	35.4	1.4	40.9	1.3
P. pumila (L. f.) Hook.			9.1	0.1				
P. furiens (Hook. & Arn.) Klotzch					4.5	0.1		
Drimys winteri var. *andina* Reiche	9.1	0.1	68.2	7.8	13.6	0.3		
Pernettya mucronata (L. f.) Gaud.			4.5	0.1				
Desfontainea spinosa Ruíz & Pav.	18.2	1.6	4.5	0.1	9.1	0.3	9.1	0.2
Berberis sp.			13.6	0.2				
Philesia magellanica Gmel.	30.3	15.2	9.1	0.1	22.7	0.1	31.8	0.4
Greigia sphacelata (Ruíz & Pav.) Regel	9.1	0.6	4.5	0.1	9.1	0.2	4.5	0.1
Herbs								
Asternanthera ovata (Cav.) Hanst	30.3	0.3	22.7	0.1	86.4	1.5	63.6	4.9
Myrteola barneoudii Berg.			4.5	0.1				
Indet. Gramineae	3.0	0.5	4.5	0.1	9.1	0.1		
Hydrocotyle sp.			4.5	0.1				
Gamochaeta sp.			4.5	0.7				
Nertera granadensis (Mutis ex L. f.) Drude					22.7	0.9	4.5	0.1
Uncina phleoides (Cav.) Pers.					4.5	0.7		
Ferns								
Gleichenia squamulosa (Desv.) Moore	45.5	0.5	90.9	1.9	13.6	0.2	4.5	0.1
Blechnum magellanicum (Desv.) Mett.	6.1	0.1	9.0	0.2	4.5	0.1	22.7	0.5
Dryopteris spectabilis (Kaulf.) Macl. & Dusen					4.5	0.1	4.5	0.1
Asplenium sp.					9.1	0.1		
Bryophytes	42.4	1.7	59.1	2.0	31.8	0.3	68.2	3.6
Trunks	48.5	18.8	50.0	14.3	50.0	12.0	45.5	10.0
Leaves, litter, and branches	100.0	57.4	100.0	47.9	100.0	68.3	95.5	34.3
Stumps					4.5	1.7		
Exposed soil and/or rock	30.0	0.5					54.5	21.3

the soils of the exploited sites. The acidity of the soils may have been slightly ameliorated by the sudden release of bases from the decaying logging debris. More importantly, the C/N ratios of the soils of the uncut Alerce forest and the exploited sites do not differ significantly. The C/N ratios are very high for a forest soil, and it is likely that available nitrogen is a limiting factor for the growth of higher plants on these soils (Brady, 1974). However, this scarcity of nitrogen cannot be attributed to the decay of the logging debris, because the C/N ratio of the uncut forest was also initially unfavourable. The soil properties measured suggest that the soils of the Contao region are extremely poor, and this is confirmed by the very slow growth-rates of *Pseudotsuga menziesii* (Mirb.) Franco and other exotic conifers that have been used there in reafforestation trials.

TABLE III

Some Soil Properties (mean ± S.E.) *of Exploited and Unexploited Alerce Sites at Contao.*

The number of samples analysed is indicated by *n*.

	Alerce forest (n = 5)	*Exploited sites (n = 15)*	*Difference between the means*	*Statistical significance (t-test)*
pH*	3.9 ±0.08	4.3 ±0.13	0.4	$P<0.05$
Percentage N†	0.89±0.19	0.62±0.11	0.27	$P>0.05$
Percentage C††	35.6 ±6.34	26.79±3.66	8.81	$P>0.05$
C/N	40.5 ±9.0	48.4 ±5.2	7.9	$P>0.05$

* 0.1 KCl (1:2).

† Kjeldahl method (titration).

†† Oxidation with potassium dichromate and colorimetric determination.

Samples analyzed in the Instituto de Suelos y Nutrición Forestal, Departamento de Silvicultura, Facultad de Ingeniería Forestal, Universidad Austral de Chile, Valdivia.

As Alerce is apparently intolerant of shading, another possible explanation of its very poor regeneration is the shading effects of *Chusquea nigricans* and the logging debris. *C. nigricans* proliferates following the clear-cutting but does not form a continuous cover. Likewise, although the logs and other logging debris form a thick layer 1–2 m in depth, this accumulation is discontinuous, covering not more than 75% of any single exploited site. If insufficient light were the cause of the lack of seedling establishment, one would expect to find at least a few seedlings in the more open sites. Thus, the reasons for this lack of regeneration are currently unknown and will have to be determined by future research on the ecology of Alerce. The three hypotheses briefly discussed below are suggested as plausible explanations which should be investigated in a series of long-term studies.

Hypothesis I

The regeneration of Alerce may occur periodically at relatively long intervals. For example, total seed production or seed viability may be very low except in unusually favourable years or series of years that are controlled either internally or climatically. Or survival of seedlings may be nil except during years of unusual weather which occur at lengthy intervals. As Alerce is a very long-lived species, seedling establishment could be very infrequent and yet sufficient to assure replacement of the parent tree. Bonnemann (1973) reports that seed production 'seems to occur annually...' though he presents no supporting data. Long-term studies should be undertaken of seed production, seed viability, and seedling survival on seed-beds treated by burning or mechanically removing organic litter as well as on untreated seed-beds.

Hypothesis II

In southern Chile, Wright (1959–60) has observed evidence of more advanced podzolization in soil profiles beneath large old conifers in comparison with surrounding soils beneath broad-leafed trees. He suggests that the buildup of litter beneath the long-lived conifers, such as Alerce, has a potent effect on leaching and accelerates the rate of soil development in a manner analogous to that of the large conifer, *Agathis australis* Salisb., in New Zealand. If this is true, the properties of the soils upon which Alerce originally established itself would have differed greatly from those of the soils beneath other forests a thousand or more years old. While the very acid and infertile state of the soils typically found under old Alerce forests is consistent with this interpretation, data are also needed on the soils of young Alerce forests, to permit further evaluation of this hypothesis.

The possible influence on soil fertility, and hence on Alerce regeneration, of the periodic deposition of volcanic ash from the explosive eruptions which have occurred throughout Quaternary time in southern Chile, must also be considered.

Hypothesis III

It is possible that Alerce is a true relict in the sense that it cannot regenerate under present climatic conditions. According to this interpretation there must have been a directional change in the climate during the past few centuries, to the point where Alerce seedlings can no longer become established. There is considerable evidence of a diminution of precipitation over the past two or three millennia. For the eastern side of the Andes at these altitudes, Kalela (1941) argues that the forest–steppe boundary has been retreating to the west for the past several centuries. The westward retreat of the forest vegetation is inferred from observations of the structure and vigour of stands located near the forest–steppe ecotone. Islands of *Nothofagus antarctica* (Forst.) Oerst. surrounded by steppe vegetation are not regenerating, and to the west, stands of *N. alpina* (Poepp. & Endl.) Oerst. show signs of decay in the form of dead tree-tops. Similarly, Kalela reports that stands of *N. dombeyi* (Mirb.) Bl. on the eastern side of the Andes are being invaded by the more drought-tolerant *N. obliqua* (Mirb.) Bl. However, much of this evidence for recent climatic change is easily explained as tree-seedling destruction by livestock. For example, during winter on the western side of the Andes at these latitudes, cattle are normally sheltered in the *Nothofagus* forests where the browsing damage is more severe on the evergreen *N. dombeyi* seedlings than on the deciduous *N. obliqua* seedlings. The westward retreat of the forests before the advancing Patagonian steppe appears to have been caused at least partially by the human use of fire and by livestock grazing in recent centuries (Eriksen, 1975).

Palynological studies by Auer (1958, 1960) clearly show an increase in the extent of the steppe vegetation in Patagonia beginning *ca* 2,200 years B.P., which is probably indicative of a long-term drying trend. On the western side of the Andes, within the present range of Alerce, Heusser's (1966, 1974) palynological studies have recently elucidated the vegetational and climatic history of this area. Heusser shows a peak of Alerce pollen 4,500-6,500 years B.P., during a cooler and moister period than the present, with a subsequent steady diminution in the importance of Alerce in the vegetation. Thus, *Fitzroya cupressoides* was declining in southern Chile centuries before the arrival of the Spaniards in the sixteenth century—very likely as a consequence of a trend towards a less cool and/or less humid climate. The continuation of this trend is indicated by the rainfall records for the city of Valdivia, which show that mean annual precipitation has been diminishing consistently since 1853 (Huber, 1970). A detailed dendrochronological investigation of the long-lived Alerces would be of considerable scientific value to the study of the recent climatic history of southern Chile as well as to the analysis of the Alerce regeneration problem.

Clearly, the three hypotheses outlined to account for the very poor regeneration of Alerce are not mutually exclusive. They are recommended as lines of future investigation.

DISCUSSION AND RECOMMENDATIONS

The case of Alerce illustrates the critical need for basic ecological research to permit the elaboration of sound policies for the preservation-management of rare and valuable tree species. Chile is considered a leader among Latin American countries in the matter of national parks development, and, under a collaborative FAO–Corporación Nacional Forestal project, considerable planning efforts are currently being made in this field (Thelen & Miller, 1976). However, owing to the paucity of previous research in the area of renewable natural resources in Chile, such planning efforts are based on a totally inadequate knowledge of the ecosystems which they purport to preserve. In the case of Alerce, it is imperative that regeneration be analysed in relation to a thorough knowledge of the local climates of all potential sites for Alerce reserves. To date, climatic data for all such sites is lacking and, consequently, scientific selection of those sites for reserves where Alerce would have the greatest chance of being preserved is not possible. The case of Alerce is just one example of the pressing need for a comprehensive research programme in the preservation and management of Chile's renewable natural resources.

Alerce is one of the more spectacular examples of the serious world-wide impoverishment of forest genetic resources (Gómez-Pompa *et al.*, 1972; FAO, 1974, 1975; Thompson, 1975; Veblen, 1976; Veblen & Delmastro, in press). The harvesting of Alerce has involved dysgenic* selection of the best phenotypes and also the clear-felling of extensive surfaces of forest. Under these practices, entire areas of provenance (and perhaps ecotypes) of Alerce have disappeared. Similarly, whole vegetation types and plant associations have been eliminated; the once-extensive lowland Alerce forests between Puerto Montt and Lago Llanquihue must have rivalled in grandeur California's Coast Redwood forests (Simmons & Vale, 1975). Thus, legal measures should be taken both to avoid further impoverishment of the Alerce gene-pool and to assure preservation of the ecosystems in which it is found.

The case of Alerce also illustrates the agonizing dilemmas that frequently arise between nature protection and short-term economic well-being in underdeveloped nations. While Alerce is not at present considered to be an endangered species, exploitation has reduced its occurrence to mainly the most remote and inaccessible sites. Despite its importance in the economic and cultural history of southern Chile, only small numbers of Chileans have seen this magnificent tree in its native habitat. Similarly, studies involving Alerce could be of substantial scientific importance in the fields of dendrochronology, plant ecology, and soil–plant relationships. Considering its scientific and cultural significance and the degree to which exploitation has already reduced its abundance, Alerce should be given total protection—such as the national monument status recently accorded *Araucaria araucana* (Mol.) C.Koch, another valuable Chilean conifer whose abundance has been much reduced by cutting.

* Detrimental to hereditary qualities of a stock or taxon, and militating against racial improvement through breeding.—Ed.

Although the present economic importance of Alerce exploitation cannot be ignored, no forester who subscribes to the philosophy of sustained-yield management of natural resources can defend the continued cutting of Alerce. Similarly, no nature preservationist can deny the human costs which would be incurred if the cutting of Alerce was effectively prohibited. Consequently, as a corollary to measures to preserve Alerce, provision should be made for alternative sources of employment for the thousands of people in southern Chile who depend, either directly or indirectly, upon the exploitation of Alerce for their livelihood.

The preservation of Alerce—like that of most other threatened species—is an international problem. The installation of Chile's largest sawmill, which is used for the cutting of Alerce at Contao, was facilitated by the availability of foreign capital and technology. Also, much of the demand for Alerce comes from outside Chile. Recently large sums of money, primarily from developed nations, have been dedicated to international programmes—such as the United Nations Environment Programme and UNESCO's Man and the Biosphere Programme—whose aim is to curtail environmental deterioration and to provide for nature protection. While these efforts are highly laudable, they have little chance of success if capital from the industrialized nations continues to be invested in the underdeveloped world without consideration of the sustained-yield philosophy and of the environmental costs. In the past few years numerous legal measures have been taken to assure the maintenance of environmental quality in most developed countries. Legal measures should now be considered to prevent the export of these environmental costs to the capital-hungry underdeveloped world.

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SUMMARY

The giant conifer, *Fitzroya cupressoides* (Mol.) Johnston, or Alerce (ah-laír-say), which is native to southern Chile and Argentina, has been intensively exploited for its durable wood since the European colonization of southern South America. Today, it persists only in relatively small stands mostly in very remote and inaccessible areas. While location in national parks provides most of the few remaining Alerce stands in Argentina with effective protection, Alerce continues to be exploited in Chile. Conservation of Chile's largest and longest-lived trees is complicated by inadequate ecological knowledge of Alerce, as well as by the socio-economic conflicts that are often associated with protection of rare but commercially valuable species.

Following exploitation, Alerce regenerates extremely poorly, though for reasons which are still unknown. Possible explanations include (1) inadequate seed production or seedling establishment in all but unusually favourable years occurring at intervals of at least ten years, (2) deterioration of the soil due to the potent leaching effect of the coniferous litter, or (3) a directional change in the climate of southern Chile since the time of establishment of much of the once-extensive forests of Alerce.

Historically, Alerce has played an important role in the economy of southern Chile since the late sixteenth century, and it continues to be commercially important. The great scientific and cultural importance of Alerce justifies giving it total protection with the status of a national monument.

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The International Centre for Industry and the Environment

Protection of the natural environment and conservation of natural resources are obvious prerequisites to Man's achieving a high quality of life. Industry is too often regarded as the despoiler of the environment and the consumer of natural resources; yet modern living is not possible without modern industry, which is thus a necessity for high-quality living. Indeed it is on industrial technology and skills that we depend in the last instance for the ability to protect the environment and its resources.

The International Centre for Industry and the Environment (ICIE) was founded by a number of major industrial federations with the help of the International Chamber of Commerce, in order to promote utilization, by intergovernmental organizations, of the extensive experience of industry in environmental protection and improvement. This contributes to the practical implementation of recommendations and other international acts in respect of the environment which, in turn, have their influence on national legislation and regulations.

The development of an industrial association for communication and consultation with intergovernmental organizations having environmental programmes, plans, and projects, began with the establishment of a Secretariat for the United Nations Environment Programme. The UNEP Secretariat, with its wide responsibility to promote coordination of international environment programmes, provided the opportunity for a coherent appreciation of the many, and often competitive, international programmes concerned with the environment.

In a close working relation with the UNEP Industry Programme in Paris and the UNEP Secretariat in general, ICIE advises its members of initiatives and developments that are of importance to industry in international environment programmes, and initiates consultation between its members and the appropriate international agency or organization on specific aspects of such programmes. Thus the managerial and operational experience of industry in implementation of measures to protect the environment, can have its influence at an early stage of international developments.

ICIE is incorporated as a non-profit company, funded entirely by the annual contributions of its member associations and industrial associates. The affairs of ICIE are managed by a committee of its full members, who are either national federations that are broadly representative of industry as a whole or else international federations of specific industries. This committee reports annually to all members and associates in a general meeting.

Regional and national federations of specific industries, individual firms, and other appropriate institutions, may join ICIE as Associates and enjoy full participation in its programme and activities. This programme is directed by a Chief Executive located in the Paris region of France.

ICIE assists industry in its liaison with the UNEP seminars on the environmental problems of specific industries. These seminars, convened by UNEP and consisting of government experts and appropriate representatives of the industry directly concerned and of other international organizations, were initiated in 1975 with one on the Pulp and Paper Industry, followed by one on the Primary Aluminium Industry and by another on the Automobile Industry. Seminars in five more sectors are either being convened or in the course of preparation, namely on Utilization of Wastes in Agriculture and Agro-industries (January 1977), on the Petroleum Industry (March 1977), on the Chemical Industry, on the Iron and Steel Industry, and on the Lead/Zinc and Cadmium Industry.

Among other activities, ICIE convenes meetings of its members and associates to discuss specific topics and with invited guest speakers. It also organizes consultations between industry and intergovernmental organizations on specific aspects of international programmes on the environment—such as the International Register of Potentially Toxic Chemicals and the Barcelona Convention on Protection of the Mediterranean.

The elected officers of ICIE are: Chairman, J.F.T. Langley (Imperial Group Ltd, London); Vice-Chairmen, F. Brandi (Elf-Mineroel, Düsseldorf) and Dr J. W. Haun (General Mills Inc., Minneapolis).

In general, ICIE advises and assists its members and associates in interpretation of the significance to them of international programmes on the environment, and attempts to communicate their practical experience on specific aspects whenever appropriate. Further information may be obtained from the undersigned:

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The German Association for the Protection of Forests and Woodlands (SDW)

This Association, the 'Schutzgemeinschaft Deutscher Wald' (SDW), was founded in 1947 in order to halt the exploitation of forests which had taken place during the war and post-war years, and to ensure the reafforestation of suitable areas in the Federal Republic of Germany. In cooperation with the Länder Forest Services, these efforts have been widely successful, though of late the protection of forests and woodlands has become even more important than reafforestation.

As an independent, non-governmental organization, mainly supported by voluntary work, the SDW, with its federal Central Office, 10 regional branches, some 300 local groups, specialized working-parties, and the *ca* 500 groups of its own youth organization (Deutsche Waldjugend), works in close collaboration with other institutions in Germany and abroad. It is a member of the International Union for Conservation of Nature and Natural Resources (IUCN) and of Europa Nostra. Leading politicians actively support its works, and its Patron is the Federal Minister for Food, Agriculture, and Forestry.

Within the Deutscher Naturschutzring (DNR), head organization of all the German non-governmental conservation associations, SDW represents the interests of the forests and their importance in the countryside—for conservation and environmental protection, as places for leisure and recreation, and as producers of vital raw materials.

Thus SDW is a key institution in developing a modern forest and conservation policy. Its task is to present modern and objective information to the public—with particular emphasis on informing the younger generation about the role of forests in a well-balanced environment, and about the need for forest management. The Association recognizes the complexity of modern forestry, whose problems cross political and administrative boundaries—quite apart from questions of different ownership.

With its media of a Journal (*Unser Wald*) and press-service, its exhibitions and working sessions, its courses for teachers and leaders in youth associations, its participation in regional planning and development control, and its cooperation with other organizations and conservation authorities, this German Association for the Protection of Forests and Woodlands is, we feel, one that could be emulated in other parts of the world with great benefit to the environment of Man and Nature. Its Central Office is at Meckenheimer Allee 79, D-5300 Bonn (Tel. 02221/658462), and its Office for International Cooperation is at Büsgenweg 5, D-3400 Göttingen (Tel. 0551/393412), Federal Republic of Germany.

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