

THE FLORA OF LLULLAILLACO NATIONAL PARK LOCATED IN THE TRANSITIONAL WINTER-SUMMER RAINFALL AREA OF THE NORTHERN CHILEAN ANDES

LA FLORA DEL PARQUE NACIONAL LLULLAILLACO UBICADO EN LA ZONA DE TRANSICION DE LAS LLUVIAS DE INVIERNO-VERANO EN LOS ANDES DEL NORTE DE CHILE

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ABSTRACT

The vascular plant flora of Llullaillaco National Park, situated mostly above 3500 m elevation in the high Andes of the II Region of Chile (24°30'S - 25°10'S; 68°30'W - 69°15'W) in the transitional zone between the summer and winter rainfall regimes, is given, along with analysis of endemism, presence of distributional limits and species-accumulation tendencies. The known flora stands at 91 species and subspecies (90 species), in 58 genera and 26 families, with an additional 3 species likely to occur in the park. Thirteen (14%) of taxa are endemic to the Chilean Andes, with two entirely restricted to the park. Outstanding numbers of taxa (35 in total: 38%) reach their northern, southern or north-south distributional limits within or very close to the park boundary. Knowledge of the park's flora has accumulated steadily since R. A. Philippi's landmark expedition to the Atacama desert in 1860. By 1925 over half of the known taxa had been collected, and by 1975 over 2/3 of the species were known. The species-accumulation curve for the park predicts that a few more species are likely to be discovered. Llullaillaco National Park plays an important role in protecting marginal populations of many high Andean species of subtropical and mediterranean affinity. The composition and characteristics of the flora indicate that the park constitutes a critical area for understanding climatic evolution in the northern Chilean Andes.

KEYWORDS: Llullaillaco National Park, II Region of Chile, northern Chilean flora, summer rainfall, winter rainfall, Andean flora, endemics, north and south distributional limits, species accumulation analysis, catalog of flora.

RESUMEN

Se presenta la flora vascular del Parque Nacional Llullaillaco, situado principalmente por sobre los 3500 m en los Andes de la II Región de Chile (24°30'S-25°10'S; 68°30'W - 69°15'W), en la zona transicional de los regímenes de lluvia de invierno y verano, junto con datos de endemismo, límites de distribución y un análisis de curvas de acumulación de especies. La flora vascular consta de 91 especies y subespecies (90 especies) distribuidas en 58 géneros y 26 familias, con 3 especies adicionales que posiblemente se encuentran en el parque. Trece (14%) taxos son endémicos a los Andes chilenos, con dos restringidos en su distribución al parque mismo. Un número destacable de taxa (35 en total: 38%) alcanzan sus límites de distribución norte, sur o sur y norte dentro o muy cerca de los límites del parque. El conocimiento de la flora del parque se ha acumulado gradualmente a partir de la histórica expedición de R. A. Philippi al desierto de Atacama en 1860. En 1925, más de la mitad de la flora había sido colectada, y en 1975 se conocía más de 2/3 de la flora. La curva de acumulación de especies del parque predice que es probable el descubrimiento de algunas especies adicionales. El Parque Nacional Llullaillaco juega un papel importante en la protección de las poblaciones marginales de un número apreciable de especies andinas de afinidad subtropical y mediterránea. La composición y características de la flora del parque indican que constituye un área crítica para la comprensión de la evolución climática de los Andes del norte de Chile.

PALABRAS CLAVES: Parque Nacional Llullaillaco, II Región de Chile, flora del norte de Chile, lluvia de verano, lluvia de invierno, flora andina, endemismo, límites de distribución norte y sur, análisis de acumulación de especies, catálogo florístico.

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INTRODUCTION

Continental Chile possesses 30 National Parks, 47 National Reserves and 13 Natural Monuments. These components of the National Protected Area System of Chile (SNASPE) cover an area of 14.4 million hectares (Muñoz *et al.* 1996), the equivalent of 19% of total land area (Arroyo & Cavieres, 1997). Over 99% of the area under protection pertains to national parks and reserves. Despite the high percentage of land area that is under protection in Chile in comparison with a world average of 6.3% (Heywood, 1995), published floristic lists and complete floras are available for relatively few protected areas. This situation is particularly evident for the northern Chilean Andes where there is no published floristic list for any protected area, other than the partial list provided by Arroyo *et al.* (1982) for Lauca National Park. The lack of floristic knowledge constitutes a serious handicap for evaluating the conservation value efficiency of the SNASPE as a whole, and for developing management plans for individual protected areas.

In this paper we provide a working checklist of the vascular plant flora of Llullaillaco National Park, II Región Chile, information on endemism and geographical ranges, and a quantitative analysis of the level of floristic knowledge of the park. The present publication was stimulated by the CONICYT-Chile Sectorial Program: "Biomás y Climas Terrestres y Marinos en el Norte de Chile" and a "Cátedra Presidencial en Ciencias" -1997 held by the first author. The "Biomás" program targeted at the regional level, enabled ample floristic exploration of poorly known areas of the II Región of Chile over the period 1996-97, development of a comprehensive data base of all vascular plant collections available for the Region, and establishment of a regional floristic list of close to 1000 taxa (Marticorena *et al.* 1998). The second initiative supports studies aimed at determining the conservation efficiency of protected areas in continental Chile situated within the area of mediterranean-type climate influence.

LLULLAILLACO NATIONAL PARK: Llullaillaco NP, comprising 262,000 hectares, was incorporated into the National Protected Area System of Chile in 1995 (Muñoz *et al.*, 1996). The area comprises one of the "Sitios Prioritarios para la Conservación de la Diversidad Biológica de Chile"

(Muñoz *et al.*, 1996). Located latitudinally between 24°30'S and 25°10'S, and longitudinally between 68°30'W and 69°15'W, with elevations mostly over 3500 m (Figure 1), this remote location is situated in the hyperarid transitional zone between the summer and winter rainfall regimes (Arroyo *et al.*, 1998, Messerli *et al.*, 1993; Fuenzalida & Rutllant, 1986, Table 1). The extremely dry climate characterizing the park, where annual precipitation is estimated to lie between 20-50 mm (Messerli *et al.*, 1993), results from the synergistic interaction between subsiding anticyclonic air masses of the southeast Pacific High Pressure Belt, the drying effect of the Humboldt current, and the rainshadow effect of the high Andes (Arroyo *et al.*, 1988; Messerli *et al.*, 1993). Winter cyclonic precipitation associated with the typical mediterranean climate in central Chile is normally blocked around 30°S, and the tropical convective summer precipitation of the "invierno boliviano" is restricted mainly to the eastern slopes of the Andes. Based on Fuenzalida & Rutllant (1986) and Aravena *et al.* (1989), both summer and winter rainfall in the transitional zone is of Amazonian origin. Winter precipitation results from the collision of wet and warm tropical and cold extra-tropical air masses. Summer precipitation is linked to an anticyclonic flow pattern in the upper troposphere over the eastern Altiplano. Vuille (1991) suggests that the amount of precipitation received during the winter in the transition zone is highly underestimated because of its solid form. The critical transition zone falls some where around 24°00'S -24°30'S, corresponding to the northern border of Llullaillaco NP. According to Vuille (1991), salt lakes north of this limit show increased water volume during the summer months; those south of 24°S show water increase as a response to winter precipitation. Based on Messerli *et al.* (1993), probably over 50% of annual precipitation received in Llullaillaco NP is of winter origin.

METHODS

The floristic information provided here is a product of botanical exploration by: a) early workers such as R.A. Philippi, C. Reiche, E. Werdermann and C. Muñoz; b) later workers such as M. T. Kalin Arroyo and G. Arancio visiting the park prior to the present study; c) the present research-

chers during the 1997 summer season. All resultant collections were incorporated into the comprehensive data base of the Flora of the II Region of Chile where they are indexed according to precise latitude and longitude, and elevation where possible. Specimens are deposited at CONC and SGO.

Presence of a species in the park was determined by defining the rectangular area: latitudes 25°30'-25°15'S and longitudes: 68°15'- 69°15'W and eliminating all specimens from the rectangle not collected within the exact boundary of the park as per in Figure 1. Some collections made very early on in the botanical history of the area are not as precise with regard to location as would be desired. The important Philippi expedition to the Atacama desert (Philippi, 1860) which resulted in many new described species for Chile, is a typical case. Philippi (1860) explored localities on the western side of the park, a number of which are problematical. For example, the elevation reported for the locality Río Frío, the latter which is clearly entirely within the limits of the park, would appear to be out by some 500 m according to present cartographic values. Collections from this locality have been accepted as pertaining to the park boundaries. It would also appear that the quoted elevations of around 3000 m for many collections from Valle or Río Zorras are underestimated. Judging by the fact that most of the plants collected at this last locality pertain to Andean bogs developed at much higher elevations, it is probable that the correct elevation is around 3500-4000 m. With this adjustment, many of the plants collected at the locality Zorras by Philippi (1860) would fall within the park boundaries.

In several instances Philippi (1860) (see also Muñoz 1960) reports visual records of species at park localities. In other cases more localities than collection numbers are cited, making it impossible to determine the precise locations of the collections. Species falling into these last two categories, that could potentially exist in the park, have been included in an Addendum to the catalog. The presence of northern and southern distributional limits within the park boundaries or very close to the latter was determined through consultation of the Chilean flora data base and literature records. The category "very close" corresponds to distributional limits found within 5' of the park boundary.

To assess the present state of floristic know-

ledge of the park, a species accumulation curve was constructed using accumulation intervals of 25 records, beginning with R. A. Philippi's collections made in 1854. The clench model (Soberón & Llorente, 1993) was used to mathematically fit the accumulation curve and to determine the effects of further collecting efforts on the park's flora.

Short descriptions and exsiccatae are given for each species.

RESULTS

HISTORICAL DEVELOPMENT OF FLORISTIC KNOWLEDGE: Figure 3 shows that species registered for the park have accumulated gradually over time. The earliest botanical collections date back to the last century when the German naturalist R. A. Philippi, then Director of the Museo Nacional de Historia Natural was directed by the government of Chile to undertake a study of the Atacama Desert (Philippi, 1860). First records of species for the park represented with a fair amount of certainty in R. A. Philippi's collections are:

- *Adesmia erinacea* Phil.
- *A. frigida* Phil.
- *Carex maritima* Gunnerus
- *Chenopodium frigidum* Phil.
- *Deyeuxia robusta* Phil.*
- *Menonvillea frigida* (Phil.) Rollins
- *Montiopsis glomerata* (Phil.) D.I.Ford
- *M. modesta* (Phil.) D.I.Ford
- *Nastanthus caespitosus* (Phil.) Reiche
- *Oxychloe andina* Phil.
- *Phacelia cumingii* (Benth.) A.Gray
- *Potamogeton strictus* Phil.
- *Puccinellia frigida* (Phil.) I.M.Johnst.
- *Ranunculus cymbalaria* Pursh f. *exilis* (Phil.)
Lourteig
- *Senecio chrysolepis* Phil.
- *Viola frigida* Phil.

Over the period 1901-1903 the German botanist Karl Reiche, also associated with the Museo Nacional de Historia Natural, effected botanical expeditions in the north of the country, including the vicinity of Volcan Lulllaillaco (Reiche, 1907), leading to the following new taxa reported for the first time within the area of park:

- *Artemisia copa* Phil.
- *Atriplex imbricata* (Moq.) D.Dietr.
- *Descurainaea stricta* (Phil.) Prantl ex Reiche
var. *minutiflora* (Phil.) O.E. Schulze
- *Fabiana bryoides* Phil.
- *Fabiana denudata* Miers
- *Junellia digitata* (Phil.) Mold.
- *Moschopsis monocephala* (Phil.) Reiche
- *Phacelia pinnatifida* Griseb ex Wedd.
- *Senecio eriophyton* J.Remy
- *Senecio sundtii* Phil.
- *Senecio xerophilus* Phil. var. *xerophilus*
- *Triglochin concinnum* Burt Davy
- *Urbania pappigera* Phil.

Between 1923 and 1927 Erich Werdermann (Werdermann 1927), later Director of Berlin Botanical Garden, undertook an expedition in the high Andes of Bolivia and northern Chile which resulted in 41 collections made in the present area of Llullaillaco NP (Looser, 1960). Species registered for the first time in the park by Werdermann include:

- *Acantholippia deserticola* (Phil.) Mold.
- *Adesmia caespitosa* Phil.
- *Arenaria serpens* Kunth
- *Astragalus cryptobotrys* I.M.Johnst.
- *Calandrinia compacta* Barnéoud
- *Catabrosa werdermannii* (Pilger) Nicora et Rúgolo
- *Cistanthe minuscula* (Añon) Peralta
- *Cistanthe picta* (Gillies ex Arn.) Carolin ex Hershk.
- *Colobanthus quitensis* (Kunth) Bartling
- *Chaetanthera revoluta* (Phil.) Cabrera
- *Cristaria andicola* Gay
- *Gilia crassifolia* Benth.
- *Hoffmannseggia eremophila* (Phil.) Burkart ex Ulib.
- *Ipomopsis gossypifera* (Gillies ex Benth.) V. Grant
- *Mancoa hispida* Wedd.
- *Montiopsis copiapina* (Phil.) D.I.Ford
- *Mulinum crassifolium* Phil.
- *Nicotiana petunioides* (Griseb.) Millan
- *Oxalis hypsophila* Phil.
- *Parastrephia quadrangularis* (Meyen) Cabrera
- *Phacelia setigera* Phil. var. *setigera*
- *Pycnophyllum bryoides* (Phil.) Rohrb.
- *Senecio hirtus* Cabrera
- *Senecio scorzoneraefolius* Meyen et Walp.
- *Sisymbrium philippianum* I.M.Johnst.

- *Stipa chrysophylla* E.Desv.
- *Viola llullaillacoensis* W.Becker

In 1944, Carlos Muñoz, then Director of the Museo Nacional de Historia Natural, explored several areas of the Atacama desert with the aim of visiting sites explored previously by R. A. Philippi (Muñoz & Pisano, 1950). Species collected within the park boundary for the first time from a total of 32 collections made, include:

- *Chaetanthera sphaeroidalis* (Reiche) Hicken
- *Deyeuxia eminens* J.Presl
- *Festuca deserticola* Phil.
- *Gentiana sedifolia* Kunth
- *Perezia atacamensis* (Phil.) Reiche
- *Nicotiana acuminata* (Graham) Hook.
- *Nototriche auricoma* (Phil.) A.W.Hill
- *Nototriche clandestina* (Phil.) A.W.Hill
- *Senecio puchii* Phil.

In 1992 G. Arancio, Universidad de La Serena, made 23 collections within the park boundary, discovering for the first time:

- *Adesmia melanthes* Phil.
- *Adesmia occulta* (R.E.Fries) Burkart
- *Baccharis tola* Phil. subsp. *altiplanicola* F.H. Hellwig
- *Deyeuxia crispa* Rugolo et Villav.
- *Festuca chrysophylla* Phil.
- *Stipa frigida* Phil.
- *Werneria pinnatifida* J.Remy

In 1994 M. T. Kalin Arroyo and collaborators, Universidad de Chile, made 82 collections within the park boundary over a period of 3 days, discovering the following species for the first time:

- *Adesmia spinosissima* Meyen
- *Astragalus bustillosii* Clos
- *Chaetanthera minuta* (Phil.) Cabrera
- *Deyeuxia deserticola* Phil.
- *Eleocharis albibracteata* Nees et Meyen ex Kunth
- *Festuca werdermannii* St.-Yves
- *Hypsela reniformis* (Kunth) K.Presl
- *Lycium humile* Phil.
- *Nicotiana longibracteata* Phil.
- *Opuntia atacamensis* Phil.
- *Ruppia filifolia* (Phil.) Skottsbo.
- *Scirpus atacamensis* (Phil.) Boeckeler
- *Sisymbrium lanatum* (Walp.) O.E.Schulze

Finally, in 1997, G. Arancio and F. Squeo, Universidad de La Serena made 29 collections within the park boundary, revealing the following previously undiscovered species:

- *Anatherostipa venusta* (Phil.) Peñail.
- *Baccharis tola* Phil. subsp. *tola*
- *Ephedra breana* Phil.
- *Lenzia chamaepitys* Phil.
- *Opuntia camachoi* Espinosa

An undated specimen of *Haplopappus rigidus* Phil. was collected at Río Frío by an unknown collector. This specimen possibly was collected by R. A. Philippi who states that it was seen only several occasions in the Atacama (Muñoz, 1960).

SPECIES ACCUMULATION ANALYSIS: A good fit of the species accumulation data was obtained with the Clench model (Figure 3; number of taxa = $(1.086887 \text{ number of collections}) + (0.007910272) \text{ number of collections}$), 99.5% explained variance). It may be seen that the species accumulation curve for Llullaillaco NP does not yet reach a clear asymptote, as would be expected if the flora were exhaustively known. Mathematical extrapolation of the curve in Figure 3 gives an expected increase in the total number of species to 110 with a doubling of the collection effort.

ENDEMISM: Endemic taxa, according to three categories of endemism are shown in Table II. The park possesses 2 local endemics: *Menonvillea frigida* (Phil.) Rollins and *Deyeuxia robusta* Phil. *Menonvillea frigida* is a very distinctive species of the genus. It was found by us growing abundantly at around 4700 m on the slopes of Volcan Llullaillaco, but would also appear to grow at lower elevations (see description). *Deyeuxia robusta* is a poorly known species, which perhaps, upon further study, will not prove different from one of the other species of *Deyeuxia* in the park. A total of 13 taxa (14.3%) of the flora is endemic to Chile.

DISTRIBUTIONAL LIMITS: Twelve species reach their northern limits in the park (Table III). Seventeen species reach their southern limits in the park. An additional 8 species reach their southern limits immediately outside the park boundary. In all 35 taxa (38.5% of the flora) are represented by their southern, northern or southern and northern limits

in the park. Relatively more species found in the zonal vegetation reach their southern limits in the park than for azonal bog habitats (Figure 4).

ADDENDUM

The following species referred to in Philippi (1860) may prove to exist in the park.

Triglochin palustris L. "Lo vi en Aguas Profetas, después en Zorras y en otras localidades semejantes" Two specimens cited (SGO 37012; 45409) (Muñoz, 1960) but it is unclear as to which localities they pertain (Muñoz, 1960).

Triglochin striatum R et P. "Lo vi más arriba de Zorras" (Muñoz, 1960). Other localities are also cited in relation to the single specimen (SGO 45410) cited.

Juncus articus var. *andicola* - was observed by R.A. Philippi at 2900 m in Zorras, which would place on the border of the park on the basis of elevation. A single specimen (SGO 37866) is cited in Muñoz (1960) as representative of the latter and other localities.

DISCUSSION

Although botanists have visited the area of Llullaillaco National Park since 1860, prior to this study no comprehensive account of the flora of Llullaillaco NP has been available (Muñoz *et al.*, 1996). Richter (1995) citing 19 species observed in a vegetation transect on Volcán Llullaillaco, is the only published reference to the botany of the park. Interestingly, however, as early as 1925, over half of the species known to occur in the park had been collected, whereas as early as 1950, over 2/3 of the flora was known.

The 90 species (91 taxa) constitute a mixture of zonal and Andean bog elements. Zonal elements include high Andean elements (e.g. *Perezia atacamensis*, *Chaetanthera sphaeroidalis*, *Stipa frigida*, *Fabiana denudata*, *Baccharis tola*, *Noto-triche* spp., *Senecio sundtii*, *S. eriophyton*, *S. puchii*, *S. xerophilus*, *Viola llullaillacoensis*, *Menonvillea frigida*, *Mulinum crassifolium*, *Pyanophyllum bryoides*, *Parastrephia quadrangularis*, *Lenzia chamaepitys*) and species representative of

the desert margin (*Acantholippia deserticola*, *Atriplex imbricata*, *Chenopodium frigidum*, *Cistanthe minuscula*, *Ephedra breana*, *Opuntia atacamensis*, *O. camochoi*, *Haplopappus rigidus*, *Gilia crassifolia*, *Hoffmannseggia eremophila*, *Ipomopsis gossypifera*). Most of the very depauperate high Andean bog flora known for this latitude is found in the park (e.g. *Calandrinia compacta*, *Colobanthus quitensis*, *Deyeuxia* spp., *Hypsela reniformis*, *Scirpus atacamensis*, *S. deserticola*, *Oxychloe andina*, *Potamogeton strictus*, *Ruppia filifolia*, *Gentiana sedifolia*). Regionally, nevertheless, the park lacks a reliable record for some of the more typical plant species associated with salt lakes (e.g. *Triglochin striatum*). Such species can be found in the Salar de Pajonales, immediately to the south of the park boundary. Inclusion of this salar in the park clearly would increase its conservation coverage.

Known species richness for the park clearly indicates an impoverished flora for a land area of 262,000 hectares in relation to other areas in the Chilean Andes. For comparison, the high Andean flora of the much smaller area of Laguna Grande and Laguna Chica in the III Región of Chile contains 281 species (Arroyo *et al.*, 1984). Monumento Nacional El Morado in the mediterranean-type climate Andes of central Chile supports 280 species in area of 3009 hectares (Tellier *et al.*, 1994). The alpine flora of Parque Nacional Torres del Paine (242,242 ha; Muñoz *et al.*, 1996) stands at 179 species in 94 genera (Arroyo *et al.*, 1992), with only a fraction of the park area supporting alpine vegetation. Nevertheless, the 90 species (91 taxa) recorded in Llullaillaco NP are within the range expected for the hyper-arid Andes. An intensive study of an altitudinal gradient slightly to the north at latitude 24°S where precipitation is slightly higher, revealed 77 species in 55 genera and 30 families over a similar elevational range (Arroyo *et al.*, 1988).

While Llullaillaco NP is not overly rich in species, it clearly plays a very important role in protecting the limiting distributions of a very large number of high Andean species. Anywhere in the Andes it is very unusual to find such a high proportion of species represented by their northern or southern distribution limits. This situation undoubtedly reflects the transitional climatic setting of Llullaillaco NP between the summer and winter rainfall regimes. Here, effectively, many northern subtropical elements adapted to a summer rainfall regime, and southern elements of mediterranean

influence adapted to a winter rainfall regime reach their southern and northern limits, respectively. Interestingly, proportionally more species reach their southern distributional limits in the park than vice-versa. The significance of this trend can only be speculated upon at this time. Around twenty seven species in the park are considered to be northern Andean elements, while 23 are considered to be of mediterranean affinity (Arroyo *et al.*, unpublished data), with the remaining species distributed in both the mediterranean and subtropical sectors of the Andes. With a predominance of northern subtropical elements in the flora, relatively more southern limits could be expected. Alternatively, the trend may simply reflect the fact that Llullaillaco NP is located slightly south of the presumed 50-50% summer-winter rainfall zone. That there are relatively more northern summer rainfall than southern mediterranean elements in the flora, suggests the hypothesis of relictual distributions of summer rainfall species. This hypothesis finds strong support in the fact that summer rainfall elements tend to be more locally distributed in the park and found in specialized habitats, such as north-facing warm rocky slopes. This last pattern is consistent with the recent findings of Grosjean *et al.* (1995) who concluded, on the basis of lake level studies, that precipitation rates between 22°-24°S in the northern Andes of Chile were intensified during the late Glacial and Holocene. According this study, annual precipitation would have been 400-500 mm higher than at present.

Species accumulation analysis indicated that some new species records can indeed be expected for the park over the 91 given here. Indeed, including the species given in the Addendum would increase the number of taxa to 94. That few additional species have been revealed in several well collected areas immediately outside the boundary of the park (e.g. Cerro Guanaqueros to the north, Quebrada de Zorras, region of Salar de Punta Negra, Sierra de Varas to the east, Salar de Pajonales, south face of Cerro del León, and Laguna de Azufrera to the south-east, and Valle Sandon to the south-west) indicates that new records are likely to be relatively few. Future botanical exploration should concentrate on the still poorly explored areas of Cerro Aguas Calientes, the south-eastern sector of Sierra de Varas, the dry pampas in the north-west sector of the park, and the northern side of Cerro del León, any small patches of high Andean bog in the north-eastern sector of the park,

and any small patches of salar vegetation that might exist within the park boundaries.

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TABLE I. Precipitation data for the closest climatic stations to Llullaillaco National Park after Hajek & di Castri (1975). CIREN y Dirección General de Aguas (DGA).

Station	Lat.	Long.	Elevat. (m)	Yrs.	Source	Annual Precipitation (mm)	Summer Precipitation (mm)
Peine	23°41'S	68°04'W	2480	17	CIREN	21.5	49.3
Socaire	23°55'S	67°52'W	3251	18	CIREN	45.6	54.5
Monturaqui	24°02'S	68°26'W	3450	5	DGA	58.5	90.0
Socompa	24°26'S	68°18'S	3915	8	CIREN	20.7	78.7
Catalina	25°14'S	69°44'W	2180	8	CIREN	0	0
Refresco	25°19'S	69°52'W	1850	19	H&D	9.2	3.3

TABLE II. Endemic vascular plants in Llullaillaco National Park. A: entirely restricted in distribution to within the boundary of the park; B: endemic to the Andes of the II Región; C: endemic to the Andes of Chile in a broader sense.

<i>Menonvillea frigida</i> (Phil.) Rollins	A
<i>Deyeuxia robusta</i> Phil.	A
<i>Descurainaea stricta</i> (Phil.) Prantl ex Reich var. <i>minutiflora</i> (Phil.) O.E.Schulz	B
<i>Opuntia atacamensis</i> Phil.	B
<i>Adesmia frigida</i> Phil.	C
<i>Baccharis tola</i> Phil. subsp. <i>altiplanicola</i> F.H. Hellwig	C
<i>Festuca werdermannii</i> St.-Yves	C
<i>Nototriche auricoma</i> (Phil.) A.W. Hill	C
<i>Nototriche clandestina</i> (Phil.) A.W. Hill	C
<i>Opuntia camachoi</i> Espinosa	C
<i>Oxalis hypsophila</i> Phil.	C
<i>Senecio hirtus</i> Cabrera	C
<i>Viola llullaillacoensis</i> W. Becker	C

TABLE III. Species with northern or southern distributional limits in, or immediately outside the border of Llullaillaco National Park. N: northern limit in park; S: southern limit in park; N and S: northern and southern limits in park; S-close: southern limit close to park boundary.

<i>Adesmia frigida</i> Phil.	N
<i>Chaetanthera minuta</i> (Phil.) Cabrera	N
<i>Festuca werdermannii</i> St.-Yves	N
<i>Montiopsis copiapina</i> (Phil.) D.I.Ford	N
<i>Montiopsis glomerata</i> (Phil.) D.I.For	N
<i>Nastanthus caespitosus</i> (Phil.) Reiche	N
<i>Senecio eriophyton</i> J.Remy	N
<i>Senecio sundtii</i> Phil.	N
<i>Viola frigida</i> Phil.	N
<i>Viola llullaillacoensis</i> W.Becker	N
<i>Deyeuxia robusta</i> Phil.	N and S
<i>Menonvillea frigida</i> (Phil.) Rollins	N and S
<i>Adesmia caespitosa</i> Phil.	S
<i>Adesmia melanthes</i> Phil.	S
<i>Anatherostipa venusta</i> (Phil.) Peñail.	S
<i>Astragalus cryptobotrys</i> I.M.Johnst.	S
<i>Baccharis tola</i> Phil. subsp. <i>altiplanicola</i> F.H.Hellwig	S
<i>Chaetanthera revoluta</i> (Phil.) Cabrera	S
<i>Descurainea stricta</i> (Phil.) Prantl ex Reich var. <i>minutiflora</i> (Phil.) O.E.Schulz	S
<i>Fabiana denudata</i> Miers	S
<i>Junellia digitata</i> (Phil.) Mold.	S
<i>Mancoa hispida</i> Wedd.	S
<i>Moschopsis monocephala</i> (Phil.) Reiche	S
<i>Nototriche auricoma</i> (Phil.) A.W.Hill	S
<i>Senecio puchii</i> Phil.	S
<i>Sisymbrium lanatum</i> (Walp.) O.E.Schulz	S
<i>Urbania pappigera</i> Phil.	S
<i>Adesmia occulta</i> (R.E.Fries) Burkart	S-close
<i>Artemisia copa</i> Phil.	S-close
<i>Deyeuxia crispa</i> Rúgolo et Villav.	S-close
<i>Opuntia atacamensis</i> Phil.	S-close
<i>Parastrephia quadrangularis</i> (Meyen) Cabrera	S-close
<i>Phacelia setigera</i> Phil. var. <i>Setigera</i>	S-close
<i>Pycnophyllum bryoides</i> (Phil.) Rohrb.	S-close
<i>Senecio xerophilus</i> Phil. var. <i>Xerophilus</i>	S-close

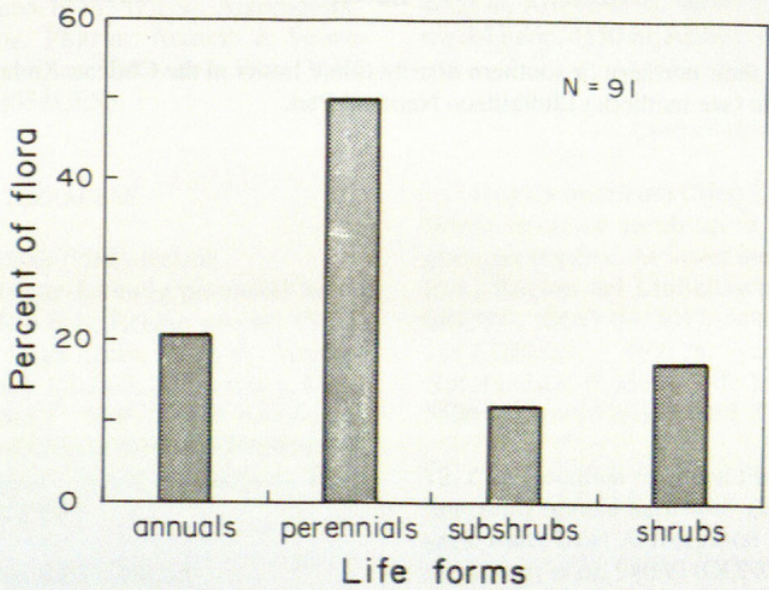


FIGURE 2. Life forms in the flora of Llullaillaco National Park. Perennials = perennial herbs. Facultatively annual species are included in the annual category.

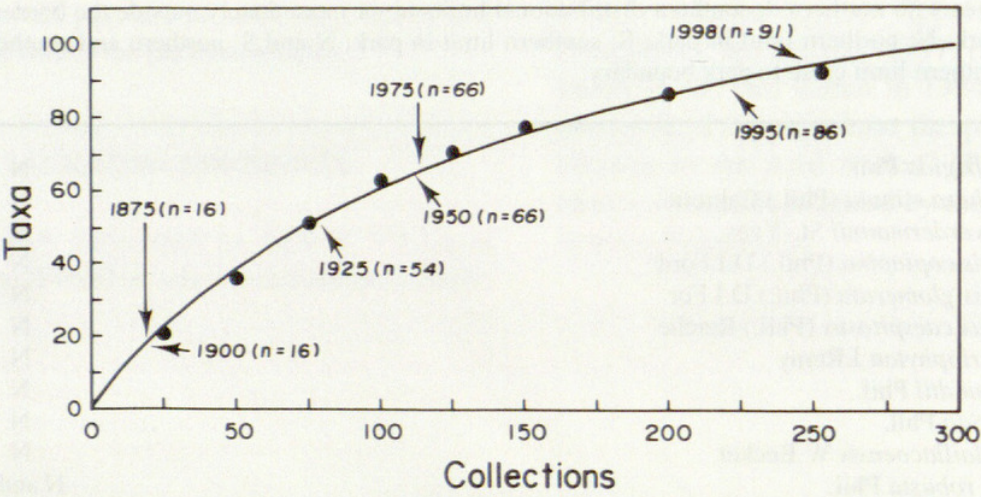


FIGURE 3. Species accumulation curve for Llullaillaco National Park, based on fitting of the Clench Model to collection data. Data points are at 25 collection intervals. The number of taxa (species and 1 subspecies) accumulated

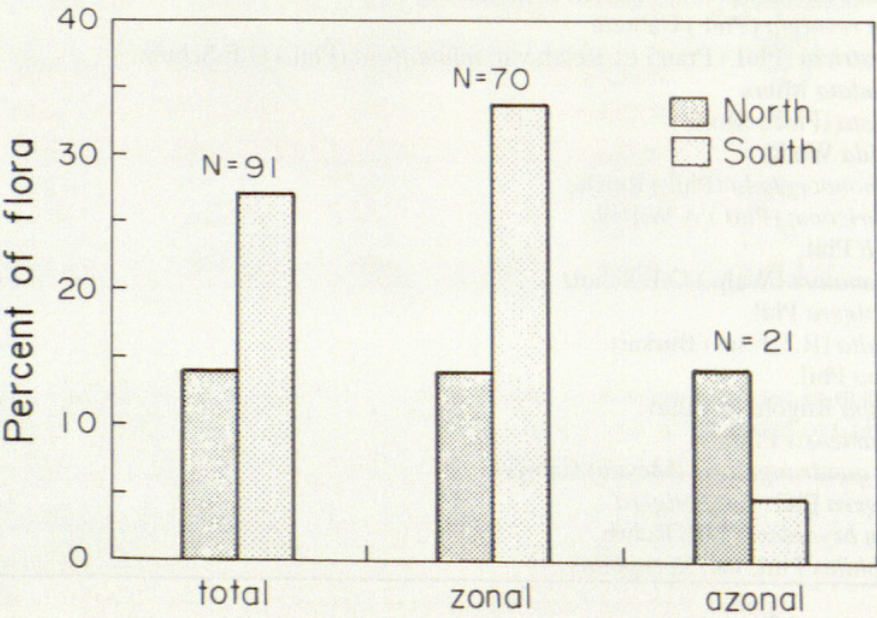


FIGURE 4. Taxa reaching their northern or southern distributional limits in the Chilean Andes within the boundaries of, or immediately outside (see methods) Llullaillaco National Park.

CATALOG OF VASCULAR PLANTS

GYMNOSPERMAE

EPHEDRACEAE

1. *Ephedra breana* Phil.

Xerophytic shrub to ca. 1.5 m with stiff, yellow-green stems; fruits fleshy, red. Exs.: Antofagasta: Llanos Cerro de la Pena, 3900 m, Arancio & Squeo 10494 (ULS).

ANGIOSPERMAE: DICOTYLEDONEAE

CACTACEAE

2. *Opuntia atacamensis* Phil.

Cushion forming species, composed of bright green ovoid or conical segments with reddish spines; flowers yellow to brownish-yellow. **Endemic** to the II Región of Chile where it is found only at mid to high elevations in the southern portion of the Región. Exs.: Antofagasta: Volcán Llullaillaco, 4100 m, Arroyo *et al.* 94025 (CONC).

3. *O. camachoi* Espinosa

Cushion forming species, closely related to *O. atacamensis*, but differing in its smaller size and grey-brown spines. **Endemic** to the high Andes of Chile (24°S-27°S). Exs.: Antofagasta: Pampa Las Carretas km 28.092, 3950 m, Arancio & Squeo 10436 (ULS).

CAESALPINIACEAE

4. *Hoffmannseggia eremophila* (Phil.) Burkart ex Ulib. Subcaulescent herb to 5 cm high. Flowers orange-red. On sandy soils. Exs.: Antofagasta: Cordillera Volcán Llullaillaco, 4000 m, Werdermann 1014 (CONC); Antofagasta: Volcán Llullaillaco, 4000 m, Arroyo *et al.* 94035 (CONC); Antofagasta: Quebrada de la Pena, 3800 m, Arancio & Squeo 10467 (ULS); Antofagasta: Llanos Cerro de la Pena, 3900 m, Arancio & Squeo 10499 (ULS); Antofagasta: Base Cerro de la Pena, 3680 m, Arancio & Squeo 10405 (ULS).

CALYCERACEAE

5. *Moschopsis monocephala* (Phil.) Reiche

Succulent, glaucous, rosette-forming perennial herb. Flowers whitish. Exs.: Río Frío, Reiche w/o no. (SGO 057228); Antofagasta: Vega Zorra, 3150 m, Arancio 92338 (ULS); Antofagasta: Llullaillaco, camino a Mina Esperanto, 3740 m, Muñoz C. 3806 (SGO); Antofagasta: Cordillera Volcán Llullaillaco, 4400 m, Werdermann 1016 (CONC); Antofagasta: Volcán Llullaillaco, 4500 m, Arroyo *et al.* 94009 (CONC).

6. *Nastanthus caespitosus* (Phil.) Reiche

Succulent, rosette-forming perennial herb. Flowers white. On edge of cushion bogs. Exs.: Río Frío, 3292 m,

Philippi w/o no. (SGO 43609, 57221); Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3891 (SGO); Antofagasta: Río Frío, 3500 m, Werdermann 1028 (CONC).

CAMPANULACEAE

7. *Hypsela reniformis* (Kunth) K.Presl

Interweaving perennial herb. Flowers white tinged blue-violet. In cushion bogs. Exs.: Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94068 (CONC).

CARYOPHYLLACEAE

8. *Arenaria serpens* Kunth

Mat forming to interweaving perennial herb. Flowers white. Common in cushion bogs. Exs.: Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94054 (CONC); Antofagasta: Cordillera Volcán Llullaillaco, 3800 m, Werdermann 1018 (CONC); Antofagasta: Volcán Llullaillaco, 3950 m, Arroyo *et al.* 94042 (CONC).

9. *Colobanthus quitensis* (Kunth) Bartling

Dwarf perennial herb. Flowers green. In cushion bogs. Exs.: Antofagasta: Volcán Llullaillaco, 3800 m, Johnston 6214 (S); Antofagasta: Volcán Llullaillaco, 3400 m, Werdermann 1452 (S).

10. *Pycnophyllum bryoides* (Phil.) Rohrb.

Common perennial herb forming loose cushions. Flowers inconspicuous, yellowish-green. Exs.: Antofagasta: Llanos en camino Quebrada de Las Zorritas, 4150 m, Arancio 248 (CONC); Antofagasta: Llullaillaco, camino a Mina Esperanto, 3740 m, Muñoz C. 3804 (SGO); Antofagasta: Cordillera Volcán Llullaillaco, 4300 m, Werdermann 1026 (CONC); Antofagasta: Volcán Llullaillaco, 4400 m, Arroyo *et al.* 94004 (CONC); Antofagasta: Cerro del León, 4150 m, Arancio & Squeo 10412 (ULS).

CHENOPODIACEAE

11. *Atriplex imbricata* (Moq.) D.Dietr.

White-stemmed shrub up to 75cm high; leaves with glaucous borders. At lower elevations on desert border. Exs.: Región del Llullaillaco, Reiche w/o no. (SGO 048299), (SGO 048301); Antofagasta: Cordillera Volcán Llullaillaco, 3800 m, Werdermann 1003 (CONC); Antofagasta: Faldeos S de la Quebrada Llullaillaco, 3500 m, Arroyo *et al.* 94081 (CONC).

12. *Chenopodium frigidum* Phil.

Spreading annual herb with glaucous foliage. On sandy sites. Rare. Exs.: Antofagasta: Volcán Llullaillaco, 4000 m, Arroyo *et al.* 94030 (CONC); Río Frío, Philippi w/o no. (SGO 48176); Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3859 (SGO).

COMPOSITAE

13. *Artemisia copa* Phil.
Aromatic shrub up to 60 cm high with whitish foliage. Locally abundant on rocky north-facing slopes. Exs.: Región del Lluillaillo, Reiche w/o no. (SGO 066433); Antofagasta: Vega Zorra, 3150 m, Arancio 92340 (ULS); Antofagasta: Volcán Lluillaillo, 4100 m, Arroyo *et al.* 94019 (CONC); Antofagasta: Volcán Lluillaillo, 4000 m, Werdermann 1007 (CONC); Antofagasta: Cerro del León, 4240 m, Arancio & Squeo 10423 (ULS).
14. *Baccharis tola* Phil. subsp. *altiplanicola* F.H.Hellwig
Yellow-stemmed, dioecious, resinous shrub usually >40 cm high. Leaves strongly dentate with 2 or more teeth on each side. Locally common on warmer north-facing rocky slopes and dry streambeds. **Endemic** to the altiplano of northern Chile. Exs.: Antofagasta: Quebrada de Las Zorritas, 3150 m, Arancio 243 (CONC); Antofagasta: Volcán Lluillaillo, 4100 m, Arroyo *et al.* 94024 (CONC); Antofagasta: Faldeos S de la Quebrada Lluillaillo, 3850 m, Arroyo *et al.* 94078 (CONC); Antofagasta: Llanos Cerro de la Peña, 3900 m, Arancio & Squeo 10493 (ULS).
15. *B. tola* Phil. subsp. *tola*
Differs from subsp. *altiplanicola* principally in its smaller stature (< 40 cm) and leaves that are entire or with 1, or exceptionally 2 teeth on each side of the lamina. Exs.: Antofagasta: Base Cerro de la Peña, 3680 m, Arancio & Squeo 10402 (ULS).
16. *Chaetanthera minuta* (Phil.) Cabrera
Decumbent annual herb, covered with a white tomentum. Heads radiate, white. On sandy soils. Exs.: Antofagasta: Volcán Lluillaillo, 4000 m, Arroyo *et al.* 94033 (CONC).
17. *Ch. revoluta* (Phil.) Cabrera
Inconspicuous perennial herb growing at base of rocks. Heads radiate, white. Common. Exs.: Antofagasta: Vega Zorra, 3150 m, Arancio 92337 (ULS); Antofagasta: Lluillaillo, camino a Mina Esperanto, 3740 m, Muñoz C. 3809 (SGO); Antofagasta: Cordillera Volcán Lluillaillo, 4200 m, Werdermann 1020 (CONC); Antofagasta: Volcán Lluillaillo, 4500 m, Arroyo *et al.* 94013 (CONC); Antofagasta: Faldeos S de la Quebrada Lluillaillo, 3850 m, Arroyo *et al.* 94079 (CONC); Antofagasta: Base Cerro de la Peña, 3680 m, Arancio & Squeo 10407 (ULS).
18. *Ch. sphaeroidalis* (Reiche) Hicken
Perennial herb forming small tight roundish rosettes covered with a whitish-pink tomentum. Heads radiate, pinkish-white. On high exposed sites, growing close to the upper vegetation limit. Exs.: Antofagasta: Lluillaillo, camino a Mina Esperanto, 3740 m, Muñoz C. 3808 (SGO); Antofagasta: Volcán Lluillaillo, 4700 m, Arroyo *et al.* 94017 (CONC); Antofagasta: Volcán Lluillaillo, 4350 m, Arroyo *et al.* 94003 (CONC); Antofagasta: S de Lluillaillo, 4800 m, Baumann 220 (CONC).
19. *Haplopappus rigidus* Phil.
Resinous, yellow-stemmed shrub. Heads radiate, yellow. The collection data upon which inclusion of this species in the park is based are very limited. Its presence needs further verification. Exs.: Antofagasta: Río Frío, w/o collector and no. (BM).
20. *Parastrephia quadrangularis* (Meyen) Cabrera
Small shrub to 50 cm with tightly imbricate greenish-yellow leaves; heads discoid, yellow. Mostly restricted to warmer rocky slopes. Exs.: Antofagasta: Valle de Zorritas, 3720 m, Muñoz C. 3830 (SGO); Antofagasta: Cordillera Volcán Lluillaillo, 4200 m, Werdermann 1012 (CONC); Antofagasta: Volcán Lluillaillo, 4150 m, Arroyo *et al.* 94026 (CONC).
21. *Perezia atacamensis* (Phil.) Reiche
Perennial herb to ca. 30 cm. Heads large, radiate, varying in color from pinkish to bluish. On rocky sites. Exs.: Antofagasta: Lluillaillo, camino Mina Esperanto, 3740 m, Muñoz C. 3805 (SGO); Antofagasta: Volcán Lluillaillo, 4500 m, Arroyo *et al.* 94014 (CONC).
22. *Senecio chrysolepis* Phil.
Erect, lightly tomentose subshrub with oblong leaves, to 20 cm. Heads discoid, yellow. Exs.: Antofagasta: Volcán Lluillaillo, 4500 m, Arroyo *et al.* 94007 (CONC); Antofagasta: Valle del Río Frío, 3200 m, Muñoz C. 3893 (SGO); Antofagasta: Río Frío, Philippi w/o no. (SGO 060675); Antofagasta: Sierra de Varas, Punta del Viento, 4200 m, Werdermann 1040 (CONC).
23. *S. eriophyton* J.Remy
Densely branched, lanose aromatic roundish dwarf shrub to 20 cm with conspicuously dentate-curved leaves. Heads radiate, yellow. Exs.: Antofagasta: Región del Lluillaillo, 4200 m, Reiche w/o no. (SI); Antofagasta: Región del Lluillaillo, 4700 m, Reiche w/o no. (SI).
24. *S. hirtus* Cabrera
Small densely branched shrub with sessile, clasping glandular-pubescent leaves, to 30 cm high. Heads radiate, yellow. **Endemic** to the high Andes of Chile (25°-28°S). Exs.: Antofagasta: Sierra de Varas, Punta del Viento, 4000 m, Werdermann 1036 (CONC).
25. *S. puchii* Phil.
Tightly branched low subshrub to 10 cm with succulent glabrous dentate leaves. Heads discoid, yellow. Exs.: Antofagasta: Faldeos Volcán Lluillaillo, Zorritas, 3800 m, Muñoz C. 3799 (SGO); Antofagasta: Volcán Lluillaillo, 4600 m, Arroyo *et al.* 94001 (CONC).
26. *S. scorzoneraefolius* Meyen et Walp.
Lax, rhizomatous perennial with conspicuously long-linear leaves. Heads discoid, dirty white. Exs.: Antofagasta: Cordillera Volcán Lluillaillo, 4200 m, Werdermann 1029 (CONC).
27. *S. sundtii* Phil.
Low, tomentose subshrub. Head discoid, yellow. Exs.: Región del Lluillaillo, Reiche w/o no. (SGO 062330);

Región del Lullaillaco, 4700 m, Reiche w/o no. (SI).

28. *S. xerophilus* Phil. var. *xerophilus*

Erect tomentose subdichotomously branched subshrub to 25 cm. Heads discoid, yellow. Exs.: Región del Lullaillaco, Reiche w/o no. (SGO 062354); Antofagasta: Vega Zorra, 3150 m, Arancio 92334 (ULS); Antofagasta: Faldeos Volcán Lullaillaco, Zorritas, 3800 m, Muñoz C. 3801 (SGO); Antofagasta: Cordillera del Volcán Lullaillaco, 4200 m, Werdermann 1037 (CONC); Antofagasta: Región del Lullaillaco, 4200 m, Reiche w/o no. (SI); Antofagasta: Volcán Lullaillaco, 4100 m, Arroyo *et al.* 94020 (CONC); Antofagasta: Volcán Lullaillaco, 4700 m, Zoellner (CONC 49070).

29. *Werneria pinnatifida* J.Remy

Rhizomatose perennial herb with fleshy pinnatisect rosette forming leaves. Heads discoid, white. Exs.: Antofagasta: Quebrada de las Zorritas, 4150 m, Arancio 335 (CONC).

CRUCIFERAE

30. *Descurainia stricta* (Phil.) Prantl ex Reiche var. *minutiflora* (Phil.) O.E. Schulz Annual to biannual, with pinnatisect leaves. Flowers minute, yellow. **Endemic** to Chile. Exs.: Región de Lullaillaco, Reiche w/o no. (SGO 071497).

31. *Mancoa hispida* Wedd.

Small, hispid perennial herb. Exs.: Antofagasta: Volcán Lullaillaco, 3800 m, Werdermann 1008 (CONC).

32. *Menonvillea frigida* (Phil.) Rollins

Perennial herb with conspicuously brown-reddish stems and leaves and showy white flowers. Grows in rock crevices. Locally common. A rare local **endemic**, thus far only known from high elevations in Parque Nacional Lullaillaco, and thus endemic to the II Región of Chile. Exs.: Antofagasta: Volcán Lullaillaco, 4700 m, Arroyo *et al.* 94006 (CONC); Antofagasta: Faldeos Volcán Lullaillaco, camino Mina Iris, 3920 m, Muñoz C. 3798 (SGO); Antofagasta: Río Frío, Philippi w/o no (SGO 063964).

33. *Sisymbrium lanatum* (Walp.) O.E.Schulz

Perennial herb, woody at the base, to ca. 30 cm, with glaucous tomentose to glabrous leaves. Flowers yellow. Exs.: Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94076 (CONC); Antofagasta: Volcán Lullaillaco, 4000 m, Arroyo *et al.* 94031 (CONC).

34. *S. philippianum* I.M.Johnst.

Subshrub to 40 cm branched at the base with tomentose stems and tomentose to glabrous leaves. Flowers yellow to purplish. Exs.: Antofagasta: Cordillera del Volcán Lullaillaco, 3500 m, Werdermann 1457 (Photo: BAA ex B).

GENTIANACEAE

35. *Gentiana sedifolia* Kunth

Small, glabrous annual to probably biannual herb. Flowers blue, with yellow centers. Grows in cushion bogs. Exs.: Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3862 (SGO).

HYDROPHYLLACEAE

36. *Phacelia cumingii* (Benth.) A.Gray

Small erect or prostrate glandular-viscid annual herb with reddish stems, pinnatisect leaves and cymose inflorescences. Flowers white. Common on sandy soils. Exs.: Antofagasta: Volcán Lullaillaco, 4000 m, Arroyo *et al.* 94029 (CONC); Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3860 (SGO); Río Frío, Philippi w/o no. (SGO 42186, 42188, 54299) Antofagasta: Base Cerro de la Pena, 3680 m, Arancio & Squeo 10403 (ULS).

37. *Ph. pinnatifida* Griseb. ex Wedd.

Erect to decumbent robust perennial herb with strongly pinnatifid leaves. Flowers blue, in dense scorpioid cymes, with exerted styles and stamens. Exs.: Cajón de Lullaillaco, Reiche w/o no. (SGO 054313).

38. *Ph. setigera* Phil. var. *setigera*

Robust, annual to perennial glandular-viscid herb with lobulate leaves and bluish-purple flowers with included styles and stamens. Exs.: Antofagasta: Cordillera Volcán Lullaillaco, 4000 m, Werdermann 1006 (CONC).

MALVACEAE

39. *Cristaria andicola* Gay

Perennial herb with yellowish stems and bright green pubescent leaves. Flowers pink. Common, in sandy soils. Exs.: Antofagasta: Quebrada de Las Zorritas, 3150 m, Arancio 241 (CONC); Antofagasta: Cordillera de Lullaillaco, 4700 m, Werdermann w/o no. (CONC 23195); Antofagasta: Volcán Lullaillaco, 4000 m, Arroyo *et al.* 94028 (CONC); Antofagasta: Cerro del León, 4240 m, Arancio & Squeo 10418 (ULS); Antofagasta: Pampa Las Carretas, 3950 m, Arancio & Squeo 10440 (ULS); Antofagasta: Pampa Las Carretas km 28,092, 3950m, Arancio & Squeo 10435 (ULS); Antofagasta: Cuesta Casa de Lata, 3700 m, Arroyo *et al.* 94100 (CONC); Antofagasta: Llanos Cerro de la Pena, 3900 m, Arancio & Squeo 10498 (ULS); Antofagasta: Base Cerro de la Pena, 3680 m, Arancio & Squeo 10404 (ULS).

40. *Nototriche auricoma* (Phil.) A.W.Hill

Caespitose tomentose perennial herb to ca. 3 cm diameter, usually partially buried in sand. Flowers white. **Endemic** to the high Andes of Chile (17°-24°S). Exs.: Antofagasta: Región de Lullaillaco, Muñoz C. 3796 (SGO); Volcán Lullaillaco, 4500 m, Arroyo *et al.* 94008 (CONC).

41. *N. clandestina* (Phil.) A.W.Hill

Compact, cushion forming perennial herb, densely covered yellowish-white tomentum. Flowers white. Grows close to the upper vegetation limit. **Endemic** to the high Andes of Chile (24°S-26°S). Exs.: Región de Lullaillaco, Muñoz C. 3797 (SGO); Antofagasta: Volcán Lullaillaco, 4500 m, Arroyo *et al.* 94018 (CONC).

OXALIDACEAE

42. *Oxalis hypsophila* Phil.

Caespitose perennial herb. Flowers yellow. **Endemic** to the high Andes of Chile (23°-31°S) Exs.: Antofagasta: Cordillera Volcán Lullaillaco, 4000 m, Werdermann 1010 (CONC).

PAPILIONACEAE

43. *Adesmia caespitosa* Phil.

Woody, flat, cushion-forming species, with short thick reddish-yellow spines; cushions often immersed in sand; flowers yellow-orange, borne on short shoots. Exs.: Antofagasta: Faldeos Volcán Lullaillaco, Zorritas, 3800 m, Muñoz C. 3803 (SGO); Antofagasta: Cordillera Volcán Lullaillaco, 4000 m, Werdermann 1025 (SI, S).

44. *A. erinacea* Phil.

Small glandular shrub forming open cushions with greenish-white, densely interwoven 3-6 bifurcate spines. Flowers yellow, generally produced on spines. Exs.: Antofagasta: Zorras, Desierto de Atacama, 3500 m, Philippi w/o no. (SGO 040253, SGO 050210); Antofagasta: Quebrada de las Zorritas, 3150 m, Arancio 245 (CONC); Antofagasta: Valle de Zorritas, 3720 m, Muñoz C. 3828 (SGO); Antofagasta: Volcán Lullaillaco, 4400 m, Arroyo *et al.* 94015 (CONC); Antofagasta: Volcán Lullaillaco, 4150 m, Arroyo *et al.* 94027 (CONC); Antofagasta: Volcán Lullaillaco, 4200 m, Baumann 286 (CONC).

45. *A. frigida* Phil.

Small caespitose glutinose-villose subshrub with 1-2 branched spines. Flowers yellow. **Endemic** to the high Andes of Chile (25°-27°S). Exs.: Antofagasta: Taltal, Punta del Viento, 4200 m, Werdermann 1023 (CONC); Río Frío, Philippi w/o no. (SGO 40179, 50241).

46. *A. melanthes* Phil.

Erect shrub to 1m with thick reddish-brown branches and spines. Leaves very small, borne on distant short-shoots. Flowers yellow. Exs.: Antofagasta: Quebrada de las Zorritas, 4150 m, Arancio 251 (CONC).

47. *A. occulta* (R.E.Fries) Burkart

Flat, hard, woody, glandular-pilose cushion forming species, partially immersed in substrate, with brownish-black spines. Flowers yellow, on short shoots. Exs.: Antofagasta: Quebrada de las Zorras, 3150 m, Arancio 92242 (ULS); Antofagasta: Volcán Lullaillaco, 4400 m, Arroyo *et al.* 94005 (CONC); Antofagasta: Volcán

Lullaillaco, 4300 m, Arroyo *et al.* 94023 (CONC).

48. *A. spinosissima* Meyen

Erect shrub to 1 m, with reddish brown stems and thick, yellowish brown to white spines. Leaves borne on short-shoots. Most abundant on sunny north-facing slopes and in dry water courses. Flowers yellow. Exs.: Antofagasta: Volcán Lullaillaco, 4000 m, Arroyo *et al.* 94022 (CONC); Antofagasta: Subida de Río Frío a Aguas Calientes, 3500 m, Arroyo *et al.* 94083 (CONC).

49. *Astragalus bustillosii* Clos

Slender, glabrous perennial herb with pale blue flowers. A cushion bog species. Exs.: Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94067 (CONC).

50. *A. cryptobotrys* I.M.Johnst.

Perennial herb forming tightly knit cushions partially immersed in substrate, with brownish-grey pubescent foliage and pinnate leaves. Flowers bluish-white. Exs.: Antofagasta: Llanos en camino a Quebrada de las Zorritas, 4450 m, Arancio 635 (CONC); Antofagasta: Sierra de Varas, Punta del Viento, 4000 m, Werdermann 1034 (CONC).

POLEMONIACEAE

51. *Gilia crassifolia* Benth.

Robust viscid annual herb to ca. 20 cm. Flowers blue to purplish-white. Mostly on desert border of park. Exs.: Antofagasta: Taltal, Punta del Viento, 3900 m, Werdermann 1030 (CONC).

52. *Ipomopsis gossypifera* (Gillies ex Benth.) V.Grant
Robust puberulent-lanose annual herb with somewhat succulent entire to pinnatisect leaves. Flowers in heads separated from the leaves; corolla rose-violet. Exs.: Antofagasta: Cordillera Volcán Lullaillaco, 4000 m, Werdermann 1041 (CONC); Antofagasta: Volcán Lullaillaco, 4000 m, Arroyo *et al.* 94039 (CONC).

PORTULACACEAE

53. *Calandrinia compacta* Barnéoud

Rhizomatose perennial herb forming extensive mats, with succulent leaves and white flowers on reddish petioles hidden among leaves. Common on edge of cushion bogs. Philippi (1860) described *Calandrinia occulta*, which he considered to be similar to *C. compacta* and *C. caespitosa*, based on material collected from the upper area of Río Zorras. We explored the higher part of quebrada Zorras, finding only 1 species of *Calandrinia* in cushion bog. Philippi's *C. occulta* is very probably a depauperate form of *C. compacta*. Exs.: Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94070 (CONC); Antofagasta: Sierra de Varas, Punta del Viento, 4000 m, Werdermann 1035 (CONC).

54. *Cistanthe minuscula* (Añon) Peralta

Diminutive annual herb with a few basal rosette long at-

tenuate, spatulate leaves. Flowers in simple or double spikes: petals white to lilac-purple. Exs.: Antofagasta: Cordillera Volcán Lluallaillaco, 3800 m, Werdermann 1015 (CONC); Antofagasta: Río Frío, 3500 m, Werdermann 1033 (CONC).

55. *C. picta* (Gillies ex Arn.) Carolin ex Hershk. Loosely branched, spreading perennial (sometimes annual?) herb with thick, glabrous, glaucous leaves, sometimes tinged red; sepals wide, with conspicuous red-black markings; petals white. Exs.: Antofagasta: Cordillera Volcán Lluallaillaco, 3800 m, Werdermann 1038 (CONC); Antofagasta: Volcán Lluallaillaco, 4000 m, Arroyo *et al.* 94038 (CONC).

56. *Lenzia chamaepitys* Phil. Diminutive perennial herb to 4 cm with closely adpressed, semi-succulent leaves and slender roots. Flowers yellow-orange, sessile, borne at tips of stems. A rare species in park, typically found on gravelly substrates. Exs.: Antofagasta: Base Cerro de la Pena, 3680 m, Arancio & Squeo 10406 (ULS).

57. *Montiopsis copiapina* (Phil.) D.I. Ford Spreading, densely sericeo-pubescent perennial herb with thick roots. Flowers conspicuous, magenta in cymose racemes. Exs.: Antofagasta: Llanos en camino a Quebrada de las Zorritas, 4150 m, Arancio 246 (CONC); Antofagasta: Vega Zorra, 3150 m, Arancio 92336 (ULS); Antofagasta: Cordillera Volcán Lluallaillaco, 4200 m, Werdermann 1021 (CONC).

58. *M. glomerata* (Phil.) D.I. Ford Small, prostrate annual herb with pubescent oblanceolate leaves. Inflorescence capitate, flowers with a densely white-pubescent calyx, petals small magenta to white. Exs.: Río Frío, 3353 m, Philippi w/o no. (SGO 48522).

59. *M. modesta* (Phil.) D.I. Ford Prostrate annual with pubescent, linear leaves. Calyx with dentate-glandular trichomes; flowers inconspicuous, magenta, in capitate inflorescences. Exs.: Antofagasta: Volcán Lluallaillaco, 4000 m, Arroyo *et al.* 94032 (CONC); Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3861 (SGO); Antofagasta: Río Frío, Philippi w/o no. (SGO 048661).

RANUNCULACEAE

60. *Ranunculus cymbalaria* Pursh f. *exilis* (Phil.) Lourteig Semi-aquatic, glabrous rhizomatous perennial herb with deeply lobed leaves. Flowers yellow with shiny, waxy petals. Grows only in cushion bogs, preferentially at the edge of water courses or standing pools. Exs.: Valle Zorras, 3351 m, Philippi w/o no. (SGO 48942); Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94074 (CONC); Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94053 (CONC).

SOLANACEAE

61. *Fabiana bryoides* Phil.

Stout shrub to ca. 50 cm, with twisted, dirty green, coral-like branches covered in scale-like leaves. Flowers white to lilac, very fragrant. Common in park on warm sunny slopes. Exs.: Región del Lluallaillaco, Reiche w/o no. (SGO 055662); Antofagasta: Vega Zorra, 3150 m, Arancio 92250 (ULS); Antofagasta: Quebrada de las Zorritas, 4450 m, Arancio 639 (CONC); Antofagasta: Valle de Zorritas, 3720 m, Muñoz C. 3829 (SGO); Antofagasta: Volcán Lluallaillaco, 4150 m, Arroyo *et al.* 94021 (CONC); Antofagasta: Cordillera Lluallaillaco, 4000 m, Werdermann w/o no. (CONC 48527); Antofagasta: Cordillera de Lluallaillaco, 4000 m, Werdermann w/o no. (CONC 22149); Antofagasta: Cerro del León, 4150 m, Arancio & Squeo 10410 (ULS); Antofagasta: Llanos Cerro de la Pena, 3900 m, Arancio & Squeo 10496 (ULS).

62. *Fabiana denudata* Miers

Strongly resinous shrub to ca. 1 m, with somewhat sinuous greenish-yellow branches and small, distant leaves. Flowers creamish-white. Locally distributed. Exs.: Región del Lluallaillaco, Reiche w/o no. (SGO 055649); Antofagasta: Cerro Zorritas, 4450 m, Arancio 252 (CONC); Antofagasta: Cordillera Volcán Lluallaillaco, 4000 m, Werdermann 1005 (CONC); Antofagasta: Faldeos S de la Quebrada Lluallaillaco, 3850 m, Arroyo *et al.* 94077 (CONC); Antofagasta: Lluallaillaco, 4000 m, w/o collector (SGO 55640).

63. *Lycium humile* Phil.

Prostrate glabrous subshrub with greyish branches, forming a dense cushion. Flowers white. Restricted to the drier edges of cushion bogs and saline soils. Exs.: Antofagasta: Volcán Lluallaillaco, 3950 m, Arroyo *et al.* 94040 (CONC).

64. *Nicotiana acuminata* (Graham) Hook.

Stout, rapidly growing annual herb with viscid stems, and distant, ovate, acuminate leaves. Flower large (5-9 cm long) greenish with purplish lines on corolla; white within. Exs.: Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3895 (SGO).

65. *Nicotiana longibracteata* Phil.

Stout, several-stemmed and densely leaved, pubescent to viscid annual herb with long-acuminate leaves. Flowers small (ca. less than 2 cm long) greenish. Philippi (1860) described *Nicotiana frigida* (SGO 55274) from Río Frío. Goodspeed (1954) suggests that this could be a depauperate form of *N. longibracteata*, but that further study is required to ascertain this possibility. This last possibility implies recognizing the name *N. frigida*, which was described before *N. longibracteata*. Further work on these species necessary. Exs.: Antofagasta: Volcán Lluallaillaco, 4000 m, Arroyo *et al.* 94037 (CONC).

66. *Nicotiana petunioides* (Griseb.) Millán

Sparsely hispid to puberulent foetid annual herb to 40 cm, with conspicuously undulate, narrow leaves. Flowers greenish-white. Common in sandy soils. Exs.:

Antofagasta: Cordillera Volcán Llullaillaco, 3800 m, Werdermann 1039 (CONC); Antofagasta: Pampa Las Carretas km 28,090, 4030 m, Arancio & Squeo 10433 (ULS); Antofagasta: Cuesta Casa de Lata, 3700 m, Arroyo *et al.* 94084 (CONC); Antofagasta: Quebrada de la Pena, 3800 m, Arancio & Squeo 10466 (ULS); Antofagasta: Llanos Cerro la Pena, 3900 m, Arancio & Squeo 10500 (ULS).

UMBELLIFERAE

67. *Mulinum crassifolium* Phil.

Softly spinose, semi-hemispheric subshrub with bright yellow-green, somewhat succulent leaves and whitish older stems. Flowers inconspicuous, greenish-yellow. Exs.: Antofagasta: Quebrada de las Zorritas, 4450 m, Arancio 640 (CONC); Antofagasta: Vega Zorra, 3150 m, Arancio 92249 (ULS); Antofagasta: Faldeos Volcán Llullaillaco, Zorritas, 3800 m, Muñoz C. 3800 (SGO); Antofagasta: Llullaillaco, camino a Mina Esperanto, 3740 m, Muñoz C. 3807 (SGO); Antofagasta: Cordillera Volcán Llullaillaco, 4300 m, Werdermann 1009 (CONC); Antofagasta: Volcán Llullaillaco, 4500 m, Arroyo *et al.* 94010 (CONC).

VERBENACEAE

68. *Acantholippia deserticola* (Phil.) Mold.

Intricately branched, strongly aromatic, spiny, white-hispid shrub to ca. 1 m with small adpressed scale-like leaves. Flowers subsessile, lilac. Mostly at lower elevations in park on desert margin. Exs.: Antofagasta: Cordillera Volcán Llullaillaco, 3500 m, Werdermann 1024 (CONC); Antofagasta: Faldeos S de la Quebrada Llullaillaco, 3500 m, Arroyo *et al.* 94082 (CONC).

69. *Junellia digitata* (Phil.) Mold.

Prostrate hispid subshrub forming isolated patches to ca. 3-5 cm, with 3-partite leaves and rust-coloured, loose bark. Flowers abundant, sweetly fragrant, dark pink. Exs.: Región del Llullaillaco, Socompa, Reiche w/o no. (SGO 054781); Antofagasta: Faldeos Volcán Llullaillaco, Zorritas, 3800 m, Muñoz C. 3802 (SGO).

70. *Urbania pappigera* Phil.

Tightly and shortly branched subshrub forming flat, inconspicuous, brownish-grey cushions typically partially immersed in substrate. Flowers inconspicuous, pink. A common species at mid-high elevations in park. Exs.: Antofagasta: Llullaillaco, camino a Mina Esperanto, 3740 m, Muñoz C. 3810 (SGO); Antofagasta: Cordillera Volcán Llullaillaco, 4500 m, Werdermann 1019 (CONC); Antofagasta: Volcán Llullaillaco, 4600 m, Arroyo *et al.* 94012 (CONC); Antofagasta: Volcán Llullaillaco, 4500 m, Arroyo *et al.* 94016 (CONC); Antofagasta: Región del Llullaillaco, 4200 m, Reiche w/o no. (SGO 068365); Antofagasta: Pampa Las Carretas km 28,092, 3950 m, Arancio & Squeo 10437 (ULS).

VIOLACEAE

71. *Viola frigida* Phil.

Rosette-forming annual herb. Flowers bluish-white. Exs.: Río Frío, 3231 m, Philippi w/o col. (SGO 052337).

72. *Viola llullaillacoensis* W.Becker

Inconspicuous, rosette-forming annual herb, leaves brownish, elliptic with ciliate margins. Flowers light blue with darker lines. Typically occurs in sandy soils. A rare species, endemic to the high Andes of Chile (24°-26°S). Exs.: Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94075 (CONC); Antofagasta: Cordillera Volcán Llullaillaco, 4000 m, Werdermann 1017 (CONC); Antofagasta: Volcán Llullaillaco, 4000 m, Arroyo *et al.* 94034 (CONC); Antofagasta: Quebrada de las Zorritas, 4200 m, Baumann 289 (CONC).

ANGIOSPERMAE: MONOCOTYLEDONEAE CYPERACEAE

73. *Carex maritima* Gunnerus

Rhizomatose perennial herb. Restricted to high elevation cushion bogs. Exs.: Valle Zorras, Philippi w/o no. (SGO 046175); Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94052 (CONC); Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94073 (CONC).

74. *Eleocharis albibracteata* Nees et Meyen ex Kunth
Caespitose, stoloniferous perennial herb. Restricted to cushion bogs. Exs.: Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94069 (CONC); Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94072 (CONC).

75. *Scirpus atacamensis* (Phil.) Boeckeler

Perennial herb forming large, tight cushions. Typically found at the drier edge of cushion bogs, where common. Exs.: Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94065 (CONC); Antofagasta: Vega Las Zorritas, 4150 m, Arroyo *et al.* 94071 (CONC); Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94064 (CONC); Antofagasta: Volcán Llullaillaco, 3950 m, Arroyo *et al.* 94041 (CONC), 94043 (CONC); 94045 (CONC).

GRAMINEAE

76. *Anatherostipa venusta* (Phil.) Peñail.

Perennial grass to 30 cm with rigid convolute glabrous yellow leaves; panicle open; aristas long, reddish and curved. Exs.: Antofagasta: Llanos Cerro de la Pena, 3900 m, Arancio & Squeo 10495 (ULS).

77. *Catabrosa werdermannii* (Pilger) Nicora et Rúgolo
Slender, inconspicuous perennial species forming loose mats. Restricted to alpine bogs. Exs.: Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3868 (SGO); Antofagasta: Taltal, Río Frío, 3500 m, Werdermann 1027 (CONC).

78. *Deyeuxia crispa* Rúgolo et Villav.

Perennial grass forming isolated clumps to 15 cm, with strongly twisted yellow leaves. Uncommon. Typically growing in warm rocky sites. Exs.: Antofagasta: Cerro Zorritas, 4450 m, Arancio 244 (CONC); Antofagasta: Volcán Lullaillaco, 4400 m, Arroyo *et al.* 94002 (CONC).

79. *Deyeuxia deserticola* Phil.

Perennial grass forming isolated tufts to 30 cm growing on large cushions, with yellowish-grey, rigid leaves. Restricted to high alpine bogs. Exs.: Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94056 (CONC), 94057 (CONC), 94058 (CONC).

80. *Deyeuxia eminens* J.Presl

Stout perennial species with junciforme leaves forming dense tussocks to 60 cm. Inflorescences large, golden-coloured, nutant. A dominant grass in high alpine cushion bogs. Exs.: Antofagasta: Valle de Zorras, 3500 m, Muñoz C. 3819 (SGO); Antofagasta: Quebrada de Zorritas, 4150 m, Baumann 299 (CONC); Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94066 (CONC); Antofagasta: Volcán Lullaillaco, 3930 m, Arroyo *et al.* 94049 (CONC), 94050 (CONC).

81. *Deyeuxia robusta* Phil.

A poorly known species. Further study might show that this species is the same as the former. Perennial herb. **Endemic** to Chile. Exs.: Valle de las Zorras 2926-3048 m, Philippi w/o no. (SGO 068418).

82. *Festuca chrysophylla* Phil.

Glabrous perennial tussock species with rigid leaves and glabrous sheaths. Apparently not common in park. Exs.: Antofagasta: Llanos en Quebrada de las Zorritas, 4450 m, Arancio 636 (CONC).

83. *Festuca deserticola* Phil.

Caespitose perennial species to ca. 35 cm. Occasional toward the desert margin. Exs.: Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3865 (SGO).

84. *Festuca werdermannii* St.-Yves

Perennial species with greyish foliage forming small tussocks. At edge of cushion bogs. Endemic to the high Andes of Chile (24°-29°S). Exs.: Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94061 (CONC), 94062 (CONC).

85. *Puccinellia frigida* (Phil.) I.M.Johnst.

Small tussock-forming species growing at drier edge of cushion bogs. Exs.: Valle Río Frío 3292 m, Philippi w/o no. (SGO 037544, 63510, 62606); Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94060 (CONC), 94063 (CONC); Antofagasta: Taltal, Cordillera Volcán Lullaillaco, 3500 m, Werdermann 1004 (CONC); Antofagasta: Volcán Lullaillaco, 3540 m, Muñoz C. 3788 (SGO); Antofagasta: Volcán Lullaillaco, 3950 m, Arroyo *et al.* 94046 (CONC).

86. *Stipa chrysophylla* E.Desv.

Caespitose perennial species with erect yellow rigid leaves to ca. 45 cm. Panicle contracted, usually exserted

above leaves. Exs.: Antofagasta: Cordillera Volcán Lullaillaco, 4500 m, Werdermann 1013 (CONC).

87. *Stipa frigida* Phil.

Perennial species with narrow rigid yellow leaves to ca. 30 cm. Panicle narrow, violet, not strongly exserted from the leaves. Very common species in the park. Exs.: Antofagasta: Llanos en camino a Quebrada de Las Zorritas, 4450 m, Arancio 637 (CONC), 638 (CONC); Antofagasta: Volcán Lullaillaco, 4500 m, Arroyo *et al.* 94011 (CONC); Antofagasta: Cerro del León, 4150 m, Arancio & Squeo 10411 (ULS); Antofagasta: Pampa Las Carretas km 28,092, 3950 m, Arancio & Squeo 10439 (ULS); Antofagasta: Cuesta Casa de Lata, 3700 m, Arroyo *et al.* 94099 (CONC); Antofagasta: Quebrada de la Pena, 3800 m, Arancio & Squeo 10464 (ULS); Antofagasta: Base Cerro de la Pena, 3680 m, Arancio & Squeo 10399 (ULS).

JUNCACEAE

88. *Oxychloe andina* Phil.

Dioecious perennial forming hard, elevated cushions with rigid, leaves. Fruits red at maturity. Dominant cushion species in alpine bogs. Exs.: Antofagasta: Valle de Zorras, Philippi w/o no. (SGO 063055); Valle de Zorritas, 3500 m, Muñoz C. 3821 (SGO); Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94055 (CONC); Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3867 (SGO).

JUNCAGINACEAE

89. *Triglochin concinnum* Burt Davy

Slender perennial herb often forming extended mats, with short, carnosely leaves, brownish stems, and erect, contracted inflorescences partially exserted above the leaves. Typically found in alpine cushion bogs. Exs.: Prov. de Antofagasta, Lullaillaco, Reiche w/o no. (SGO 045420); Antofagasta: Cordillera Volcán Lullaillaco, 3500 m, Werdermann 1011 (CONC); Antofagasta: Volcán Lullaillaco, 3950 m, Arroyo *et al.* 94044 (CONC).

POTAMOGETONACEAE

90. *Potamogeton strictus* Phil.

Aquatic perennial herb with submerged elongate cylindrical stems and filiform, membranous leaves; flowers disposed in small spikes. In pools in high alpine bogs. Exs.: Valle de Zorras, 3261 m, Philippi w/o no. (SGO 45443); Antofagasta: Valle de Río Frío, 3200 m, Muñoz C. 3863 (SGO).

RUPPIACEAE

91. *Ruppia filifolia* (Phil.) Skottsb.

Submerged, aquatic perennial herb. Growing in slow-flowing water courses in high alpine bogs. Exs.: Antofagasta: Vega Las Zorritas, 4200 m, Arroyo *et al.* 94051 (CONC); Antofagasta: Volcán Lullaillaco, 3950 m, Arroyo *et al.* 94047 (CONC).

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