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AREAS OF ENDEMISM IN THE SOUTHERN CENTRAL ANDES

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Abstract. Aagesen, L.; M. J. Bena, S. Nomdedeu, A. Panizza, R. P. López & F. O. Zuloaga. 2012. Areas of endemism in the southern central Andes. *Darwiniana* 50(2): 218-251.

This paper analyzes the distribution of vascular plants species endemic to the southern central Andes (south-western Bolivia and north-western Argentina). All 540 species endemic to the study regions (approx. 720600 km^2) have been included in the analysis. The main part of the endemic species is found in semiarid habitats between 1500-3500 m asl pointing to the topographically complex plateau, slope, and valley system of the southern central Andes as the main locations for its endemic flora. The distribution of the endemic species within arid sites is in contrast with that of vascular plant diversity in general, as the most diverse habitat of the region is the moist subtropical Tucumano-Bolivian Yungas forest of the eastern Andes slope. A total of 17 well defined and partly overlapping distribution patterns were indentified. The broadest distribution pattern defines a general area of endemism for the southern central Andes. This area extends through nearly the entire region and is defined by species that are widespread within the region in desert to sub-humid environments of the high Andes, slopes, or valleys. Nearly all other areas of endemism are nested within this broad distribution pattern as successively north-south overlapping areas along the slopes and valleys of the Andes and the Pampeanas Range. Despite the distributional bias of endemism towards the arid sites almost half of the endemic species are restricted to a few high endemic areas that lie in juxtaposition to the main rainfall zones. These areas contain the widest habitat ranges in terms of altitude and rainfall within the region with the endemic species being equally variable in altitude and moisture requirements. Previous defined phytogeographic units were not recognized among the distribution patterns. However, the northern part of the Prepuna can be defined as two partly overlapping distribution patterns.

Keywords. Areas of endemism; Argentina; biogeography; Bolivia; endemic vascular plants; southern central Andes.

Resumen. Aagesen, L.; M. J. Bena, S. Nomdedeu, A. Panizza, R. P. López & F. O. Zuloaga. 2012. Áreas de endemismo en el sur de los Andes Centrales. *Darwiniana* 50(2): 218-251.

Este trabajo analiza la distribución de especies de plantas vasculares endémicas de la porción sur de los Andes centrales (sudoeste de Bolivia y noroeste de Argentina). En el análisis se incluyeron 540 especies endémicas de la región estudiada (aproximadamente 720.600 km^2). La mayoría de las especies endémicas se halla en ambientes semiáridos, entre 1500-3500 m s.m., encontrándose principalmente en valles, laderas y mesetas del topográficamente complejo sur de los Andes centrales. Las áreas de endemismos aquí halladas se presentan consecuentemente en ambientes áridos y no en ambientes húmedos subtropicales de las Yungas tucumano-bolivianas, a pesar de que en esta última región la diversidad de plantas vasculares es mayor. Se identificaron un total de 17 patrones de distribución bien definidos, y parcialmente solapados. El patrón de distribución más amplio define un área general de endemismos para los Andes centrales. Esta área se extiende a lo largo de casi toda la región y está delimitada por especies que se distribuyen en ambientes desérticos a sub-húmedos en laderas, valles o regiones altoandinas. Casi todas las restantes áreas de endemismo se encuentran anidadas dentro del patrón de distribución amplio antes citado, superponiéndose en el sentido norte-sur a lo largo de pendientes y valles de los Andes y de las Sierras Pampeanas. A pesar del sesgo observado en la distribución hacia ambientes

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áridos, aproximadamente la mitad de las especies endémicas están restringidas a unas pocas áreas de alto endemismo, las que se encuentran en yuxtaposición con las zonas más lluviosas de la región. Estas áreas de alto endemismo incluyen los rangos de hábitat más amplios de la región en términos de altitud y precipitación, siendo las especies endémicas igualmente variables en sus requerimientos de humedad y elevación. Las unidades fitogeográficas previamente definidas por diversos autores no fueron encontradas entre los patrones de distribución hallados; no obstante, la parte norte de la provincia Prepuneña puede ser definida con dos patrones de distribución parcialmente superpuestos.

Palabras clave. Áreas de endemismo; Argentina; biogeografía; Bolivia; plantas vasculares endémicas; sur de los Andes centrales.

INTRODUCTION

Located in the centre of the South American dry diagonal, the southern central Andes have received relatively little attention in terms of quantitative phytogeographic studies. At a continental scale, hotspots and areas of endemism have mainly been defined and explored in more humid portions of the Andes, such as the northern Andes or northern central Andes (e.g. Kier et al., 2005; Orme et al., 2005; Sklenář et al., 2011) and in the southern Andes (Arroyo et al., 1999, 2004; Rodríguez-Cabral et al., 2008).

Within the southern cone of South America the endemic vascular flora is concentrated in the well documented Chilean hotspot (Arroyo et al., 1999, 2004; Bannister et al., 2012 and references therein). However, the arid southern central Andes appear to be the second most important area of endemism, as checklists and catalogues show that north-western Argentina contains far more endemic species than the remaining of the region including Uruguay, southern Brazil, and southern Paraguay (Zuloaga et al., 1999, 2008).

During the Tertiary, the central Andes became relatively dryer than the northern and southern part (Simpson & Todzia, 1990). Comparative floristic studies along the Andes have identified the flora of the southern central Andes as a separate unit among other arid plant formations (López et al., 2006) and found more similarities at generic and family level between the high Andean flora of the humid northern and southern Andes than between these and the high Andean flora of the dry central Andes (Simpson & Todzia, 1990). Summer rainfall is sufficiently high on the eastern slopes to support humid subtropical Yungas forest that is one of the most diverse habitats within the southern cone (Brown, 1995). However, no quantitative studies have examined whether endemism in the southern central Andes is related to the Yungas forest or found within the more arid vegetation on the inner slopes and valleys.

In their biogeographic analysis of South America, Cabrera & Willink (1973) and Cabrera (1976) emphasised the distinctiveness of the slope vegetation in the southern central Andes by differentiating the vegetation between 2400-3500 m asl as the Prepuna phytogeographic province. The Prepuna was originally restricted to north-western Argentina (Cabrera, 1976), but later expanded to include the dry inter-Andean valleys of southern Bolivia (López, 2000, 2003). Since the phytogeographic units in the traditional scheme of Cabrera are based on the presence of endemic taxa (Cabrera, 1951, 1953; Ribichich, 2002) it is reasonable to expect that at least part of the endemic species are distributed along the Prepuna, therefore defining the limits of this phytogeographic unit.

Here we explore the distribution pattern of the vascular plant species endemic to the southern central Andes including the Prepuna province in its entire extension. Defining areas of endemism is considered fundamental for historical and ecological biogeography (Crisp et al., 2001), but also for conservation studies especially if endemism is found out of the high diverse vegetation types as protected area systems focus on diversity hotspots (Orme et al., 2005). Our main aims are to explore how the endemic species are distributed within the southern central Andes, identify areas of endemism, and examine to which extent these main areas of endemism correspond to pre-established phytogeographic units such as the Prepuna slope vegetation, or found within the high diverse Yungas forest. We used the optimality criterion developed by Szumik et al. (2002) and Szumik & Goloboff (2004) and implemented in the program NDM/VNDM (Goloboff, 2005) to analyze the distribution of the species endemic to the north-western Argentina and south-western Bolivia.

MATERIALS AND METHODS

Study Region

The study region comprises all west Argentinean provinces between the Bolivian border and ~32º S as well as the adjacent southern Bolivia departments of Tarija, Chuquisaca, and Potosí (see maps in Fig. 1-2). The Chaco basin towards the east (Fig. 1) and the hyper arid northern Chile to the west make natural borders of the study region while the southern limit follows the northern limit of the Patagonian biogeographic province (Cabrera, 1979; Cabrera & Willink, 1973; Morrone, 2001). The northern limit follows López (2000) and López & Beck (2002), authors who analyzed the floristic composition of the Bolivian Prepuna and stressed the floristic relationship between the southern Bolivia and the north-western Argentina (see also Ibisch et al., 2003). The study region comprises approx. 720.600 km^2.

Rainfall mainly occurs during the southern hemisphere summer where the South American Monsoon System (SAMS) brings moist air to the region (Zhou & Lau, 1998). The influence of the SAMS decreases by an east-west and north-south gradient (Fig. 2A). In the southernmost part of the study region rainfall due to the SAMS is low while winter rain is higher due to the influence of the Pacific westerlies that brings winter rain to central Chile (Montecinos & Aceituno, 2003).

Traditionally the study region has been divid-

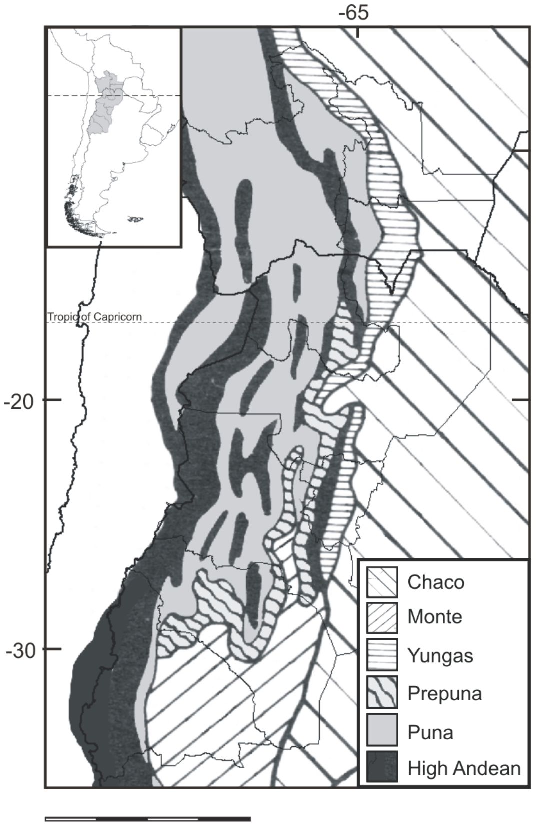

Fig. 1. Study region, classic phytogeographic scheme based on Cabrera and Willink (1973). Scale bar = 400 km.

Table 1. General results for all analyses under different grid sizes, consensus criterion (%), and consensus rules (ae and aa). For more information on consensus rules and criterion see Materials and Methods.

	0.2º x 0.2º		**0.5º x 0.5º**		**0.5º x 1.0º**	
	25%-50%	**50%-75%**	**10%-20%**	**25%-50%**	**10-20%-5-10%**	**25%-50%**
Sub-sets (number of defining species)	**72 (144)**	**125 (192)**	**783 (365)**	**695 (425)**	**958 (425)**	**826 (505)**
ae 50%	48	64	305	264	355	286
ae 33%	39	52	211	184	248	203
ae 10%	29	40	104	106	123	92
ae 5%	28	37	87	82	92	70
aa 50%	40	48	80	65	81	64
aa 33%	25	26	29	22	7	8
aa 10%	15	17	9	7	2	2
aa 5%	14	17	9	7	2	2

Table 2a. List of endemic species. Each species is assigned to the area of endemism in which it obtained the best score. Altitudinal ranges were obtained from the georeferenced locations and therefore are suggestive - not observed field data. For area names see Table 2b.

		Cell Size					
Familiy	**Species** (number of georeferenced records)	**0.2x0.2**	**0.5x0.5**	**1x0.5**	**Altitude range (mas)**	**Aridity range**	**Área**
Alstroemeriaceae	*Alstroemeria bakeri* Pax (5)		0.85		1580 - 3000	5.6 - 15.6	1
Amaryllidaceae	*Habranthus pictus* Ravenna (1)	0.92			1420	15.7	1
Apocynaceae	*Philibertia coalita* (Lillo) Goyder (3)		0.82		1420 - 3040	12.1 - 15.7	1
Asteraceae	*Hieracium lorentzianum* Zahn (8)		0.83		2700 - 3720	7.3 - 18.1	1
Asteraceae	*Hieracium sordidum* Griseb. (8)		0.85		2700 - 3460	6.3 - 18.1	1
Asteraceae	*Hieracium vervoorstii* Sleumer (1)		1.00		2825	15.9	1
Asteraceae	*Luciliocline catamarcense* (Cabrera) Anderb. & S.E. Freire (1)	0.90	0.75		3270	11.4	1
Asteraceae	*Senecio ambatensis* Cabrera (1)	0.77	0.88		3460	18.1	1
Bromeliaceae	*Puya harmsii* (A. Cast.) A. Cast. (5)		0.82		1690 - 3410	7.3 - 12.2	1
Cactaceae	*Acanthocalycium glaucum* F. Ritter (3)		0.86		1500 - 1900	5.6 - 9.0	1
Cactaceae	*Gymnocalycium hybopleurum* (K. Schum.) Backeb. (7)		0.87	0.40	1045 - 1910	5.9 - 17.5	1
Cactaceae	*Lobivia crassicaulis* Backeb. ex R. Kiesling (1)	0.21	0.71		2170	14.3	1
Calyceraceae	*Boopis castillonii* (Hicken) Pontiroli (1)	0.77	0.88		3460	18.1	1
Convolvulaceae	*Cuscuta argentinana* Yunck. (6)		0.70	0.78	1160 - 2930	5.9 - 15.6	1
Dioscoreaceae	*Dioscorea trifurcata* Hauman (1)	0.92			1420	15.7	1
Fabaceae	*Lupinus burkartianus* C.P. Sm. (2)		0.67		2960 - 3615	6.3 - 14.1	1
Fabaceae	*Senna pachyrrhiza* (L. Bravo) H.S. Irwin & Barneby (1)	0.48	0.83		2240	6.6	1
Iridaceae	*Sisyrinchium biflorum* Griseb. (2)		0.83		2700 - 3460	13.3 - 18.1	1
Poaceae	*Agrostis ambatoensis* Asteg. (1)	0.77	0.88		3460	18.1	1
Poaceae	*Digitaria catamarcensis* Rúgolo (2)		1.00		480 - 520	12.8 - 12.9	1
Poaceae	*Nassella catamarcensis* Torres (1)		0.79		1675	18.1	1
Poaceae	*Nassella ragonesei* Torres (4)		0.61		1670 - 1960	8.8 - 18.1	1
Solanaceae	*Solanum crebrum* C.V. Morton ex L.B. Sm. (1)	0.83	0.83		1710	14.1	1
Solanaceae	*Solanum mortonii* Hunz. (4)		1.00		730 -1120	12.6 - 13.9	1
Verbenaceae	*Verbena andalgalensis* Moldenke (1)	0.83			2650	9.0	1
Violaceae	*Viola joergensenii* W. Becker (1)	0.81			3750	12.5	1
Asteraceae	*Aphyllocladus ephedroides* Cabrera (6)		0.32	0.82	1000 - 2150	3.8 - 5.3	2
Asteraceae	*Huarpea andina* Cabrera (3)		0.76	0.70	3245 - 3945	7.3 - 8.2	2
Asteraceae	*Senecio cremnophilus* I.M. Johnst. (3)		0.74	0.69	3520 - 4150	7.3 - 10.6	2
Boraginaceae	*Cryptantha latefissa* R.L. Pérez-Mor. (1)			0.75	2405	5.0	2
Brassicaceae	*Sarcodraba andina* O.E. Schulz (2)		0.70	0.71	2900 - 4250	6.5 - 8.1	2
Fabaceae	*Adesmia sanjuanensis* Burkart (2)			0.77	2375 - 3245	7.8 - 9.7	2
Fabaceae	*Astragalus boelckei* Gómez-Sosa (4)		0.69	0.63	3570 - 4530	7.4 - 24.1	2
Fabaceae	*Astragalus nelidae* Gómez-Sosa (6)			0.66	3320 - 4810	8.7 - 27.2	2
Fabaceae	*Astragalus pulviniformis* I.M. Johnst. (1)		0.72	0.75	3530	7.5	2
Juncaceae	*Oxychloë castellanosii* Barros (7)		0.50	0.55	3550 - 4440	4.4 - 24.1	2
Malvaceae	*Nototriche copon* Krapov. (4)		0.81	0.77	4095 - 4305	7.6 - 17.9	2
Poaceae	*Nassella famatinensis* Torres (4)		0.67	0.69	3195 - 4070	8.9 - 14.8	2
Solanaceae	*Solanum glaberrimum* C.V. Morton (4)		0.75	0.77	1650 - 2590	4.4 - 5.7	2
Valerianaceae	*Valeriana corynodes* Borsini (3)			0.70	2910 - 4090	9.9 - 19.9	2
Violaceae	*Viola flos-evae* Hieron. (2)		0.70	0.83	3430 - 4070	12.8 - 14.8	2
Asteraceae	*Aphyllocladus spartioides* Wedd. (22)		0.72	0.54	2030 - 3480	6.6 - 21.2	3

Table 2a. Continued.

Asteraceae	*Flourensia fiebrigii* S.F. Blake (15)		0.82	0.76	2540 - 3975	8.4 - 18.1	3
Bromeliaceae	*Deuterocohnia strobilifera* Mez (5)			0.79	2540 - 3600	11.7 - 17.8	3
Fabaceae	*Cercidium andicola* Griseb. (20)		0.63	0.54	2160 - 4060	8.3 - 19.6	3
Fabaceae	*Prosopis ferox* Griseb.(30)		0.79	0.47	2411 - 4030	6.9 - 19.2	3
Oxalidaceae	*Oxalis cotagaitensis* Griseb. (6)			0.89	2500 - 3500	9.9 - 17.0	3
Amaryllidaceae	*Chlidanthus marginatus* (R.E. Fr.) Ravenna (2)		0.67		3680 - 3750	8.8 - 8.9	4
Apocynaceae	*Philibertia micrantha* (Malme) Goyder (2)		0.79	0.71	3460 - 3705	10.5 -15.2	4
Asteraceae	*Chuquiraga acanthophylla* Wedd. (8)		0.76		3355 - 3810	6.7 - 18.6	4
Asteraceae	*Dasyphyllum hystrix* (Wedd.) Cabrera (2)	0.78	0.87		3355 - 3620	12.1 - 18.6	4
Asteraceae	*Gochnatia cardenasii* S.F. Blake (15)		0.58		2410 - 3880	9.7 - 20.4	4
Asteraceae	*Senecio jujuyensis* Cabrera (7)		0.69	0.90	3360 - 4380	7.2 - 13.7	4
Bromeliaceae	*Tillandsia camargoensis* L. Hrom. (2)		0.63		2600 - 2980	12.4 - 17.8	4
Cactaceae	*Cleistocactus tupizensis* (Vaupel) Backeb. & F.M. Knuth (3)	0.80	0.80		2540 - 3620	12.1 - 17.8	4
Cactaceae	*Opuntia ferocior* (Backeb.) G.D. Rowley (3)	0.69	0.85		3355 - 3930	12.1 - 18.6	4
Cactaceae	*Oreocereus celsianus* (Lem. ex Salm-Dyck) Riccob. (7)		0.78		2990 - 3165	13.1 - 16.1	4
Cactaceae	*Oreocereus trollii* (Kupper) Backeb. (9)		0.84	0.62	3340 - 4090	8.8 - 18.6	4
Cactaceae	*Parodia maassii* (Heese) A. Berger (13)		0.83	0.64	2710 - 3760	10.0 - 19.0	4
Cactaceae	*Tephrocactus chichensis* Cárdenas (3)		0.78		3020 - 3930	13.1 - 17.8	4
Cactaceae	*Trichocereus tacaquirensis* (Vaupel) Cárdenas ex Backeb. (5)		0.85		2500 - 3190	15.1 - 17.6	4
Cactaceae	*Trichocereus werdermannianus* Backeb. (7)		0.81		3070 - 3290	11.4 - 18.2	4
Fabaceae	*Acacia feddeana Harms* (14)		0.80		2410 - 3165	12.3 - 18.3	4
Iridaceae	*Mastigostyla cabrerae* R.C. Foster (3)		0.64	0.77	3830 - 4100	6.8 - 10.1	4
Ledocarpaceae	*Balbisia integrifolia* R. Knuth (3)		0.78		3110 - 3355	15.6 - 19.5	4
Malvaceae	*Abutilon fuscicalyx* Ulbr. (8)		0.58		1370 - 3670	13.8 - 24	4
Solanaceae	*Iochroma cardenasianum* Hunz. (8)		0.73		3050 - 3140	15.0 - 18.1	4
Zygophyllaceae	*Bulnesia rivas-martinezii* G. Navarro (6)		0.73		2870 - 3190	15.9 - 26.3	4
Acanthaceae	*Justicia riojana* Lindau (6)		0.68		1810 - 3195	5.5 - 11.1	5
Amaryllidaceae	*Habranthus andalgalensis* Ravenna (8)		0.54	0.67	510 - 1670	7.6 - 14.5	5
Asteraceae	*Chiliotrichiopsis ledifolia* (Griseb.) Cabrera (3)		0.77		2490 - 3410	7.3 - 9.6	5
Asteraceae	*Flourensia blakeana* M.O. Dillon (4)		0.58		1240 - 2860	7.0 - 10.8	5
Asteraceae	*Flourensia tortuosa* Griseb. (12)		0.81	0.61	1110 - 3250	5.5 - 14.4	5
Asteraceae	*Hysterionica pulchella* Cabrera (6)		0.76	0.70	2270 - 4375	7.5 - 18.1	5
Asteraceae	*Senecio toroanus* Cabrera (3)			0.58	1030 - 2780	4.6 - 10.4	5
Bromeliaceae	*Tillandsia tenebra* L. Hrom. & W. Till (5)			0.58	1030 - 2070	5.9 - 14.7	5
Cactaceae	*Gymnocalycium baldianum* (Speg.) Speg. (6)			0.50	750 - 1960	11.6 - 19.6	5
Cactaceae	*Gymnocalycium pugionacanthum* Backeb. ex H. Till (7)		0.77		845 - 2180	5.7 - 12.5	5
Cactaceae	*Trichocereus andalgalensis* (F.A.C. Weber) Hosseus (10)			0.70	780 - 2180	8.9 - 19.7	5
Cactaceae	*Trichocereus cabrerae* R. Kiesling (4)		0.73	0.80	920 - 3690	8.1 - 12.9	5
Cactaceae	*Trichocereus huascha* (F.A.C. Weber) Britton & Rose (7)			0.72	190 - 2100	5.4 - 13.8	5
Fabaceae	*Adesmia pseudoincana* Burkart (2)		0.64		995 - 1710	10.7 - 14.1	5
Fabaceae	*Lupinus alivillosus* C.P. Sm. (3)	0.86	0.71		3180 - 4070	12.2 - 14.8	5
Fabaceae	*Lupinus tucumanensis* C.P. Sm. (4)	0.59	0.62		1860 - 4070	11.0 - 14.8	5
Gentianaceae	*Gentianella claytonioides* (Gilg) T.N. Ho & S.W. Liu (5)		0.77		2910 - 3690	9.5 - 18.1	5
Gentianaceae	*Gentianella kurtzii* (Gilg) Fabris (5)		0.39		3640 - 3840	4.8 - 14.8	5
Poaceae	*Poa plicata* Hack. (9)		0.75	0.69	2700 - 4470	8.0 - 18.6	5
Ranunculaceae	*Ranunculus lancipetalus* Griseb. (8)		0.74		670 - 4080	5.8 - 15.7	5

Table 2a. Continued.

Rosaceae	*Lachemilla asplenifolia* (Rothm.) Rothm. (2)	0.83	0.74		2560 - 2700	9.6 - 13.3	5
Solanaceae	*Sclerophylax cynocrambe* (Griseb.) Griseb. (10)		0.86		930 - 2330	5.6 - 8.9	5
Verbenaceae	*Aloysia catamarcensis* Moldenke (11)		0.47	0.68	760 - 2100	6.1 - 15.2	5
Violaceae	*Viola triflabellata* W. Becker (9)		0.78	0.73	2330 - 4375	8.7 - 18.1	5
Amaryllidaceae	*Habranthus riojanus* Ravenna (2)		0.62		2815 - 3030	6.7 - 10.7	6
Asteraceae	*Aphyllocladus decussatus* Hieron. (1)	0.63			2330	8.5	6
Asteraceae	*Baccharis famatinensis* Ariza (1)	0.69			2490	8.8	6
Asteraceae	*Flourensia niederleinii* S.F. Blake (5)		0.60	0.57	1550 - 2100	4.5 - 10.2	6
Asteraceae	*Senecio cremnicola* Cabrera (1)	0.86	0.88		4070	14.8	6
Asteraceae	*Senecio famatinensis* Cabrera (1)	0.74	0.75		3780	12.0	6
Asteraceae	*Senecio krapovickasii* Cabrera (1)	0.86	0.88		4070	14.8	6
Asteraceae	*Senecio lanosissimus* Cabrera (3)		0.73	0.73	1770 - 3195	5.1 - 10.9	6
Asteraceae	*Senecio niederleinii* Cabrera (2)	0.64	0.88		3165 - 3690	9.8 - 12.9	6
Brassicaceae	*Menonvillea famatinensis* (Boelcke) Rollins (1)	0.86	0.88		4070	14.8	6
Cactaceae	*Gymnocalycium ritterianum* Rausch (2)	0.91	0.80	0.83	1405 - 1860	8.1 - 8.4	6
Cactaceae	*Trichocereus pseudocandicans* Backeb. ex R. Kiesling (3)	0.44	0.88		1380 - 2100	7.0 - 8.8	6
Cactaceae	*Trichocereus vatteri* R. Kiesling (2)	0.85			1630 - 1860	7.9 - 8.4	6
Fabaceae	*Lupinus hieronymi* C.P. Sm. (1)	0.86	0.88		2560	9.6	6
Gentianaceae	*Gentianella riojae* (Gilg) Fabris ex J.S. Pringle (2)		0.92		2250 - 4090	11.9 - 15.0	6
Malvaceae	*Nototriche famatinensis* A.W. Hill (1)	0.86	0.88		4070	14.8	6
Malvaceae	*Nototriche glabra* Krapov. (1)	0.86	0.88		4070	14.8	6
Malvaceae	*Nototriche kurtzii* Krapov. (1)	0.86	0.75		3970	13.8	6
Malvaceae	*Nototriche niederleinii* A.W. Hill (4)	0.87	0.88		3950 - 4090	12.6 - 15.0	6
Malvaceae	*Nototriche pulvilla* A.W. Hill (2)	0.87	0.88		3950 - 4090	12.6 - 15.0	6
Verbenaceae	*Acantholippia riojana* Hieron. ex Moldenke (3)		0.76		1155 - 1670	5.3 - 7.6	6
Asteraceae	*Isostigma molfinianum* Sherff (2)		0.46	0.84	850 - 880	8.7 - 10.8	6*
Cactaceae	*Gymnocalycium albiareolatum* Rausch (6)		0.70		1110 - 1550	10.1 - 10.2	6*
Cactaceae	*Gymnocalycium kieslingii* O. Ferrari (3)		0.91	0.81	1260 - 1360	9.3 - 11.8	6*
Cactaceae	*Gymnocalycium mazanense* (Backeb.) Backeb. (5)		0.76	0.71	740 - 1270	7.4 - 11.4	6*
Cactaceae	*Gymnocalycium mucidum* Oehme (3)		0.81		740 - 1010	7.2 - 11.0	6*
Cactaceae	*Gymnocalycium uebelmannianum* Rausch (2)		0.77	0.79	1425 - 2240	9.8 - 11.2	6*
Anacampserotaceae	*Anacampseros vulcanensis* Añon (3)		0.89	0.38	2255 - 2270	13.8 - 17.0	7
Apocynaceae	*Philibertia castillonii* (Lillo ex T. Mey.) Goyder (2)	0.84	1.00		1440 - 3100	11.2 - 27.7	7
Asteraceae	*Eupatorium arachnoideum* Legname (2)	0.79	0.88		1220 - 1495	28.0 - 28.6	7
Asteraceae	*Eupatorium hickenii* Cabrera & Vittet (2)	0.05	0.89	0.57	1860 - 2190	16.4 - 18.3	7
Asteraceae	*Hieracium kieslingii* Cabrera (1)	0.81	1.00		2720	16.7	7
Asteraceae	*Hieracium luteomontanum* Cabrera (1)	0.81	1.00		2720	16.7	7
Asteraceae	*Laennecia altoandina* (Cabrera) G.L. Nesom (2)	0.76	0.81	0.54	3605 - 4100	10.1 - 10.4	7
Asteraceae	*Perezia volcanensis* Cabrera (1)	0.86	1.00	0.50	2270	17.0	7
Asteraceae	*Senecio altoandinus* Cabrera (1)	0.90		0.88	3770	9.6	7
Asteraceae	*Senecio keshua* Cabrera (2)	0.83	0.93	0.26	3950 - 4270	10.8 - 14.5	7
Asteraceae	*Senecio tilcarensis* Cabrera (3)	0.76	0.76		3480 - 4110	9.4 - 12.5	7
Asteraceae	*Senecio yalae* Cabrera (2)	0.64	0.88		2190 - 3450	13.3 - 18.3	7
Asteraceae	*Stevia crassicephala* Cabrera (2)	0.79	1.00		1920 - 2190	18.3 - 23.9	7
Asteraceae	*Stevia yalae* Cabrera (2)	0.62	1.00	0.50	2190 - 2670	14.2 - 18.3	7
Bromeliaceae	*Puya assurgens* L.B. Sm. (2)	0.89	1.00	0.50	2190 - 2970	12.6 - 18.3	7

Table 2a. Continued.

Cactaceae	*Lobivia densispina* (Werderm.) Buining (2)	0.85	0.92	0.50	2560 - 2640	13.8 - 14.6	7
Cactaceae	*Lobivia gonjianii* (R. Kiesling) R. Kiesling (2)	0.80	0.79		3360 - 3810	9.9 - 10.7	7
Cactaceae	*Lobivia jajoiana* Backeb. (1)	0.77			3337	10.5	7
Cactaceae	*Lobivia marsoneri* (Werderm.) Backeb. (1)	0.84		0.65	4100	10.1	7
Cactaceae	*Parodia chrysacanthion* (K. Schum.) Backeb. (3)	0.69	0.92	0.50	2010 - 3055	11.8 - 20.7	7
Cactaceae	*Pyrrhocactus umadeave* (Werderm.) Backeb. (3)		0.66	0.74	2750 - 3510	8.1 - 10.5	7
Cactaceae	*Rebutia marsoneri* Werderm. (2)	0.86	1.00	0.50	1890 - 2270	17.0 - 17.9	7
Cactaceae	*Trichocereus fabrisii* R. Kiesling (1)	0.86	1.00	0.50	3100	11.2	7
Cactaceae	*Tunilla tilcarensis* (Backeb.) D.R. Hunt & J. Iliff (1)	0.92	0.69		2930	10.2	7
Caryophyllaceae	*Pycnophyllum mucronulatum* Mattf. (1)	0.79	0.88		3395	13.2	7
Convolvulaceae	*Cuscuta friesii* Yunck. (2)	0.87	0.78	0.51	3430 - 3750	10.0 - 10.9	7
Crassulaceae	*Sedum jujuyense* Zardini (3)	0.65	1.00	0.50	1800 - 2270	17.0 - 23.9	7
Dioscoreaceae	*Dioscorea castilloniana* Hauman ex Castillón (3)	0.75	1.00	0.50	2190 - 2640	14.6 - 18.3	7
Fabaceae	*Adesmia arenicola* (R.E. Fr.) Burkart (1)	0.48		0.80	3510	8.4	7
Malvaceae	*Nototriche macrotuba* Krapov. (1)	0.81		0.65	4750	12.6	7
Malvaceae	*Tarasa latearistata* Krapov. (1)	0.84	0.88		3450	12.0	7
Orchidaceae	*Chloraea cogniauxii* Hauman (3)	0.71	0.96		2640 - 3980	11.2 - 14.6	7
Plantaginaceae	*Plantago jujuyensis* Rahn (3)	0.91	0.92	0.50	2670 - 3900	11.2 - 14.2	7
Urticaceae	*Pilea jujuyensis* Sorarú (2)		0.81		1170 - 1675	25.8 - 27.3	7
Velloziaceae	*Barbaceniopsis humahuaquensis* Noher (4)	0.86	1.00	0.50	1740 - 2270	17.0 - 25.3	7
Verbenaceae	*Junellia ballsii* (Moldenke) N. O'Leary & P. Peralta (3)	0.46	0.97	0.50	4000 - 4150	10.8 - 12.2	7
Acanthaceae	*Aphelandra lilacina* C. Ezcurra (1)	0.83			1420	26.3	7*
Apiaceae	*Mulinum axilliflorum* Griseb. (9)			0.81	3500 - 4810	5.4 - 12.7	7*
Apocynaceae	*Macropharynx meyeri* (C. Ezcurra) Xifreda (4)		0.77		950 - 1640	25.7 - 27.5	7*
Apocynaceae	*Matelea schreiteri* (T. Mey.) Pontiroli (7)		0.55		480 - 1860	16.4 - 29.0	7*
Apocynaceae	*Philibertia affinis* (Griseb.) Goyder (1)			0.80	970	21.5	7*
Aristolochiaceae	*Aristolochia oranensis* Ahumada (2)		0.71		1380 - 2210	20.3 - 27.9	7*
Asteraceae	*Gamochaeta longipedicellata* Cabrera (2)	0.54	0.69	0.65	3520 - 4100	10.0 - 10.1	7*
Asteraceae	*Mutisia saltensis* Cabrera (2)	0.09	0.70		1155 - 1620	25.4 - 26.8	7*
Asteraceae	*Senecio tocomarensis* Cabrera (1)	0.83	0.66	0.68	4400	7.0	7*
Asteraceae	*Stevia centinelae* Cabrera (1)	0.27	0.66		1880	26.6	7*
Asteraceae	*Vernonia lipeoensis* Cabrera (5)	0.80	0.79		1495 - 1630	25.5 - 28.0	7*
Asteraceae	*Vernonia novarae* Cabrera (1)		0.80		360	33.7	7*
Brassicaceae	*Exhalimolobos burkartii* (Romanczuk & Boelcke) Al-Shehbaz & C.D. Bailey (2)		0.81		380 - 1260	23.5 - 31.8	7*
Brassicaceae	*Lepidium jujuyanum* Al-Shehbaz (1)	0.70	0.90	0.50	3750	10.4	7*
Brassicaceae	*Petroravenia eseptata* Al-Shehbaz (1)	0.92	0.66	0.68	4520	7.8	7*
Bromeliaceae	*Pitcairnia saltensis* L.B. Sm. (1)			0.88	1110	30.9	7*
Bromeliaceae	*Puya micrantha* Mez (4)		0.76		1750 - 2000	20.6 - 27.0	7*
Cactaceae	*Parodia nivosa* Backeb. (1)	0.83			2620	11.4	7*
Celastraceae	*Maytenus cuezzoi* Legname (4)	0.88	0.79		1495 - 1660	25.1 - 28.0	7*
Cucurbitaceae	*Sicyos ignarus* Mart. Crov. (1)	0.80			1710	25.5	7*
Euphorbiaceae	*Acalypha friesii* Pax & K. Hoffm. (1)		0.75		570	25.5	7*
Fabaceae	*Astragalus fabrisii* Gómez-Sosa (2)				4140 - 4940	6.8	7*
Fabaceae	*Astragalus punae* I.M. Johnst. (1)				4070	5.2	7*
Gentianaceae	*Gentianella multiflora* (Griseb.) Fabris (2)		0.68	0.75	2720 - 3280	13.2 - 16.6	7*

Table 2a. Continued.

Iridaceae	*Cypella elegans* Speg. (2)		0.73		470 - 2450	17.7 - 23.6	7*
Malvaceae	*Nototriche cabrerae* Krapov. (2)	0.92	0.66	0.68	4520	7.8	7*
Piperaceae	*Peperomia aldrinii* Villa (1)		0.80		360	33.7	7*
Poaceae	*Anatherostipa henrardiana* (Parodi) Peñailillo (2)			0.73	4505 - 4810	5.4 - 9.0	7*
Poaceae	*Aristida pedroensis* Henrard (1)			0.88	570	20.5	7*
Poaceae	*Chusquea deficiens* Parodi (1)	0.90	0.70		1640	26.5	7*
Poaceae	*Jarava breviseta* (Caro & E.A. Sánchez) Peñailillo (2)		0.70		3230 - 3430	9.2 - 10.9	7*
Poaceae	*Nassella novari* Torres (11)		0.72	0.82	2530 - 4010	7.9 - 13.7	7*
Rubiaceae	*Psychotria argentinensis* Bacigalupo (5)	0.33	0.67		1290 - 1770	24.1 - 29.1	7*
Solanaceae	*Solanum fabrisii* Cabrera (1)		0.66		1480	28.0	7*
Solanaceae	*Solanum zuloagae* Cabrera (2)		0.85		1355 - 1750	21.2 - 27.0	7*
Tropaeolaceae	*Tropaeolum willinkii* Sparre (2)		0.68	0.77	350 - 460	24.2 - 27.9	7*
Amaryllidaceae	*Zephyranthes andina* (R.E. Fr.) Traub (4)		0.77		2075 - 3230	9.2 - 21.6	7**
Apocynaceae	*Metastelma microgynostegia* Pontiroli (5)		0.77		785 - 1390	22.7 - 31.6	7**
Asteraceae	*Flourensia suffrutescens* (R.E. Fr.) S.F. Blake (8)		0.69	0.87	2650 - 3750	8.0 - 15.4	7**
Asteraceae	*Microliabum humile* (Cabrera) Cabrera (3)		0.90	0.83	2750 - 3900	12.0 - 17.3	7**
Asteraceae	*Mikania jujuyensis* Cabrera (3)		0.57		1495 - 2190	18.3 - 28. 0	7**
Asteraceae	*Senecio infimus* Cabrera (6)	0.88	0.88	0.80	2670 - 4250	11.2 - 17.3	7**
Asteraceae	*Senecio punae* Cabrera (12)		0.78	0.88	3460 - 4350	6.2 - 15.2	7**
Asteraceae	*Stevia jujuyensis* Cabrera (4)		0.80		1155 - 1470	26.7 - 30.3	7**
Asteraceae	*Trichocline macrorhiza* Cabrera (6)		0.88	0.78	2600 - 4330	8.1 - 18.9	7**
Begoniaceae	*Begonia sleumeri* L.B. Sm. & B.G. Schub. (3)	0.80	0.88		2600 - 3280	11.9 - 18.9	7**
Brassicaceae	*Dictyophragmus punensis* (Romanczuk) Al-Shehbaz (5)	0.82	0.88	0.51	2530 - 4100	10.1 - 13. 7	7**
Brassicaceae	*Mancoa venturii* Al-Shehbaz (5)		0.78	0.78	2270 - 4140	6.8 - 17.0	7**
Cactaceae	*Lobivia einsteinii* (Fric) Rausch (10)		0.86	0.76	2940 - 4160	7.1 - 12.9	7**
Cactaceae	*Lobivia nigricans* Wessner (5)		0.60	0.80	2610 - 2930	8.3 - 13.5	7**
Cactaceae	*Maihueniopsis minuta* (Backeb.) R. Kiesling (4)		0.83		2640 - 3890	10.5 - 13.7	7**
Cactaceae	*Parodia stuemeri* (Werderm.) Backeb. (8)		0.74	0.76	2255 - 3030	9.0 - 20.1	7**
Caryophyllaceae	*Silene bersieri* Bocquet (3)		0.75		2670 - 4150	11.8 - 16.6	7**
Caryophyllaceae	*Silene haumanii* Bocquet (4)		0.75	0.74	3770 - 4110	6.6 - 13.7	7**
Convolvulaceae	*Ipomoea volcanensis* O'Donell (9)		0.74		1590 - 2460	17.0 - 26.7	7**
Fabaceae	*Adesmia friesii* Burkart ex Ulibarri (7)		0.83	0.85	2270 - 4110	8.4 - 17.0	7**
Fabaceae	*Lupinus jujuyensis* C.P. Sm. (2)	0.16	0.80	0.93	3500 - 4070	9.0 - 10.5	7**
Malvaceae	*Nototriche castillonii* B.L. Burtt & A.W. Hill (3)		0.79	0.79	4000 - 4410	10.1 - 16.5	7**
Malvaceae	*Nototriche friesii* A.W. Hill (3)	0.57	0.77	0.80	4010 - 5080	14.6 - 16.5	7**
Orobanchaceae	*Bartsia jujuyensis* Cabrera & Botta (9)		0.77	0.63	1605 - 4160	10.7 - 27.7	7**
Poaceae	*Anatherostipa brevis* (Torres) Peñailillo (4)	0.80	0.94		3100 - 3680	11.2 - 15.6	7**
Poaceae	*Aristida pubescens* Caro & E.A. Sánchez (5)		0.70	0.83	3260 - 3830	7.0 - 11.8	7**
Poaceae	*Eragrostis andicola* R.E. Fr. (21)		0.85		2270 - 4000	8.4 - 17.0	7**
Solanaceae	*Solanum calileguae* Cabrera (5)		0.66		1390 - 2680	16.5 - 30.3	7**
Valerianaceae	*Valeriana altoandina* Cabrera (5)		0.73	0.87	4080 - 4810	8.4 - 16.6	7**
Amaryllidaceae	*Hippeastrum aglaiae* (A. Cast.) Hunz. & Cocucci (13)		0.73		1200 - 2860	11.8 - 34.7	8
Anthericaceae	*Anthericum hickenianum* Poelln. (8)		0.81	0.79	1540 - 2270	15.2 - 28.0	8
Apiaceae	*Bowlesia hieronymusii* H. Wolff (3)		0.79	0.85	2385 - 4150	11.8 - 16.9	8
Apocynaceae	*Oxypetalum tucumanense* (T. Mey.) Goyder & Rapini (3)	0.81	0.88	0.80	1150 - 1500	17.9 - 40.4	8
Apocynaceae	*Philibertia barbata* (Malme) Goyder (14)		0.85		1330 - 3100	11.4 - 26.8	8

Table 2a. Continued.

Apocynaceae	*Philibertia cionophora* (Griseb.) Goyder (6)	0.82	0.85	0.78	1150 - 1920	21.3 - 40.3	8
Asteraceae	*Flourensia macroligulata* Seeligm. (3)		0.76	0.78	2110 - 2640	6.9 - 17.0	8
Asteraceae	*Senecio catamarcensis* Cabrera (4)		0.89	0.79	2270 - 3980	11.4 - 17.0	8
Bromeliaceae	*Puya lilloi* A. Cast. (13)		0.76	0.79	830 - 2730	13.8 - 34.4	8
Bromeliaceae	*Puya smithii A. Cast.* (5)		0.77	0.82	710 - 3180	12.2 - 24.8	8
Bromeliaceae	*Tillandsia friesii* Mez (4)		0.82	0.74	2110 - 3290	6.9 - 11.2	8
Cactaceae	*Rebutia minuscula* K. Schum. (15)		0.79	0.88	1070 - 2710	10.3 - 28.0	8
Cactaceae	*Trichocereus thelegonus* (F.A.C. Weber) Britton & Rose (3)		0.72		460 - 1465	11.2 - 33.3	8
Euphorbiaceae	*Acalypha schreiteri* Lillo ex Lourteig & O´Donell (4)	0.83	0.83	0.71	820 - 2070	17.1 - 27.4	8
Fabaceae	*Astragalus burkartii* I.M. Johnst. (7)		0.73	0.46	1705 - 4670	8.5 - 20.1	8
Gentianaceae	*Gentianella cosmantha* (Griseb.) J.S. Pringle (4)		0.79	0.61	1760 - 2190	9.7 - 18.3	8
Gentianaceae	*Gentianella tubulosa* (Gilg) Fabris (7)		0.87	0.77	3100 - 4250	9.5 - 14.8	8
Iridaceae	*Cardenanthus venturi* R.C. Foster (2)		0.89	0.73	3950 - 4110	13.6 - 16.2	8
Iridaceae	*Ennealophus simplex* (Ravenna) Roitman & A. Castillo (3)		0.81	0.87	2700 - 3040	12.2 - 13.3	8
Loasaceae	*Caiophora nivalis* Lillo (9)		0.75	0. 80	2830 - 4610	7.5 - 19.1	8
Malvaceae	*Tarasa meyeri* Krapov. (8)		0.83	0.84	2850 - 3890	8.9 - 13.4	8
Orchidaceae	*Chloraea subpandurata* Hauman (7)		0.90	0.83	1820 - 2970	12.6 - 22.0	8
Orchidaceae	*Sacoila secundiflora* (Lillo & Hauman) Garay (4)		0.79		460 - 1590	24.5 - 32.5	8
Solanaceae	*Solanum collectaneum* C.V. Morton (10)		0.69	0.79	390 - 1495	23.4 - 33.6	8
Solanaceae	*Solanum delitescens* C.V. Morton (18)		0.83	0.72	710 - 1920	22.8 - 36.6	8
Solanaceae	*Solanum venturii* Hawkes & Hjert. (7)		0.93	0.88	2140 - 3040	10.7 - 20.3	8
Tropaeolaceae	*Tropaeolum argentinum* Buchenau (9)		0.76	0.62	790 - 2270	10.8 - 29.0	8
Valerianaceae	*Valeriana tucumana* Borsini (6)	0.46	0.97	0.86	1150 - 3040	12.2 - 40.3	8
Acanthaceae	*Dicliptera cabrerae* C. Ezcurra (8)		0.80	0.66	2110 - 2170	12.6 - 17	8*
Alstroemeriaceae	*Bomarea macrocephala* Pax (13)		0.84	0.91	1580 - 3250	8.0 - 22.0	8*
Alliaceae	*Schickendantziella trichosepala* (Speg.) Speg. (4)		0.83	0.88	2640 - 3100	7.2 - 18.0	8*
Amaranthaceae	*Gomphrena radiata* Pedersen (8)		0.68	0.45	2650 - 3660	5.2 - 12.9	8*
Amaryllidaceae	*Hieronymiella speciosa* (R.E. Fr.) Hunz. (11)		0.77	0.93	1160 - 4035	6.8 - 15.2	8*
Anacardiaceae	*Schinus gracilipes* I.M. Johnst. (11)		0.66	0.68	690 - 3460	8.75 - 28.2	8*
Anthericaceae	*Anthericum argentinense* (Hauman) Guagl. (9)		0.78	0.86	1110 - 2640	9.1 - 22.7	8*
Apiaceae	*Austropeucedanum oreopansil* (Griseb.) Mathias & Constance (6)		0.72	0.80	830 - 3395	12.2 - 34.5	8*
Apocynaceae	*Philibertia nivea* (Griseb.) Goyder (7)		0.70	0.43	1420 - 3070	9.2 - 30.4	8*
Asteraceae	*Flourensia riparia* Griseb. (17)		0.49	0.53	770 - 3285	5.2 - 28. 0	8*
Asteraceae	*Gnaphalium yalaense* Cabrera (1)	0.82	1.00	0.50	2190	19.0	8*
Asteraceae	*Gutierrezia repens* Griseb. (6)		0.75	0.60	2880 - 4540	9.7 - 18.1	8*
Asteraceae	*Hieracium niederleinii* (Zahn) Sleumer (6)	0.77	0.73	0.88	2400 - 3040	10.7 - 18.2	8*
Asteraceae	*Hieracium tucumanicum* (Zahn) Sleumer (8)		0.77	0.91	1880 - 3100	9.1 - 17.1	8*
Asteraceae	*Holocheilus fabrisii* Cabrera (4)		0.76	0.66	1605 - 2140	16.7 - 27.7	8*
Asteraceae	*Hysterionica aberrans* (Cabrera) Cabrera (4)		0.85	0.73	980 - 4110	15.6 - 23.8	8*
Asteraceae	*Senecio cremeiflorus* Mattf. (11)		0.77	0.78	650 - 2600	12.8 - 34.4	8*
Asteraceae	*Senecio flagellifolius* Cabrera (4)		0.73	0.76	1980 - 3270	10.4 - 32.5	8*
Asteraceae	*Trichocline exscapa* Griseb. (17)		0.65	0.75	2325 - 4470	5.3 - 8.1	8*
Berberidaceae	*Berberis lilloana* Job (11)		0.80	0.72	1400 - 2570	9.1 - 30.7	8*
Brassicaceae	*Draba burkartiana* O.E. Schulz (4)		0.79	0.80	3350 - 4400	11.8 - 16.6	8*
Brassicaceae	*Parodiodoxa chionophila* (Speg.) O.E. Schulz (8)		0.64	0.75	3460 - 5000	9.6 - 18.6	8*

Table 2a. Continued.

Brassicaceae	*Polypsecadium tucumanense* (O.E. Schulz) Al-Shehbaz (2)	0.79	0.84		3040 - 3615	12.2 - 14.1	8*
Bromeliaceae	*Puya volcanensis* Castillón (3)		0.78		2670 - 3720	11.0 - 14.8	8*
Bromeliaceae	*Tillandsia zecheri* W. Till (2)	0.44	0.74		1985 - 2740	6.1 - 6.2	8*
Cactaceae	*Gymnocalycium spegazzinii* Britton & Rose (28)		0.57	0.71	1290 - 3160	7.5 - 17.2	8*
Cactaceae	*Rebutia deminuta* (F.A.C. Weber) A. Berger (3)		0.72	0.71	2000 - 3000	11.48 - 20.72	8*
Caryophyllaceae	*Stellaria cryptopetala* Griseb. (22)		0.77	0.73	1860 - 4350	6.6 - 16.6	8*
Convolvulaceae	*Ipomoea lilloana* O'Donell (6)		0.59	0.90	750 - 2320	10.3 - 31.7	8*
Cucurbitaceae	*Pteropepon argentinense* Mart. Crov. (7)		0.81	0.81	350 - 2610	11.5 - 28.1	8*
Cyperaceae	*Carex pseudomacloviana* G.A. Wheeler (1)	0.86	0.73		3280	16.6	8*
Fabaceae	*Astragalus joergensenii* I.M. Johnst. (9)		0.75	0.88	1670 - 3220	8.5 - 17.0	8*
Fabaceae	*Lupinus austrorientalis* C.P. Sm. (5)		0.73	0.71	3110 - 4000	5.9 - 16.6	8*
Fabaceae	*Lupinus ultramontanus* C.P. Sm. (3)		0.73	0.78	2030 - 4090	13.6 - 17.4	8*
Gentianaceae	*Gentianella bromifolia* (Griseb.) T.N. Ho & S.W. Liu (6)	0.76	0.83	0.89	2600 - 3940	11.0 - 18.1	8*
Gentianaceae	*Gentianella hieronymi* (Gilg) Fabris (16)		0.81	0.82	3395 - 4580	10.4 - 17.8	8*
Geraniaceae	*Geranium leucanthum* Griseb. (11)		0.78	0.85	1660 - 3180	12.2 - 26.4	8*
Iridaceae	*Ennealophus fimbriatus* Ravenna (12)		0.76	0.79	820 - 3240	9.1 - 29.0	8*
Martyniaceae	*Craniolaria argentina* Speg. (7)		0.66	0.72	400 - 2130	6.3 - 28.0	8*
Montiaceae	*Phemeranthus punae* (R.E. Fr.) Eggli & Nyffeler (7)		0.76	0.73	3260 - 3860	7.0 - 14.1	8*
Poaceae	*Festuca superba* Parodi ex Türpe (14)		0.83	0.83	1800 - 3940	12.2 - 25.9	8*
Poaceae	*Festuca uninodis* Hack. (3)				3400 - 4160	8.9 - 13.3	8*
Poaceae	*Nassella arcaënsis* (Speg.) Torres (12)		0.70	0.76	2270 - 4140	5.3 - 19.6	8*
Poaceae	*Nassella parva* Torres (8)		0.76	0.75	2270 - 3460	10.7 - 18.1	8*
Poaceae	*Poa ragonesei* Nicora (2)		0.59		1710 - 1840	15.2 - 25.5	8*
Poaceae	*Tragus andicola* Zapater & Sulekic (17)		0.78	0.88	1900 - 3690	6.7 - 15.5	8*
Polygonaceae	*Rumex lorentzianus* Lindau (6)	0.78	0.85	0.89	2300 - 3460	11.0 - 18.1	8*
Rosaceae	*Tetraglochin paucijugatum* (I.M. Johnst.) Rothm. (8)		0.86	0.51	2460 - 3400	10.1 - 15.9	8*
Rubiaceae	*Manettia jorgensenii* Standl.(9)		0.81	0.90	1490 - 2430	12.8 - 19.6	8*
Solanaceae	*Solanum montigenum* (C.V. Morton) Cabrera (6)		0.68	0.79	470 - 3460	9.2 - 24.7	8*
Solanaceae	*Solanum vernei* Bitter & Wittm. (6)		0.77	0.85	2270 - 3100	9.7 - 17.0	8*
Urticaceae	*Urtica lilloi* (Hauman) Geltman (4)		0.69		1130 - 1840	15.2 - 28.4	8*
Valerianaceae	*Valeriana polybotrya* (Griseb.) Höck (10)		0.75	0.64	730 - 3410	7.3 - 19.2	8*
Verbenaceae	*Glandularia lilloana* (Moldenke) Botta (17)		0.55	0.52	295 - 3100	6.8 - 27.9	8*
Verbenaceae	*Lantana magnibracteata* Tronc.(13)		0.46	0.90	330 - 2270	9.9 - 26.6	8*
Verbenaceae	*Lantana tilcarensis* Tronc. (11)		0.72	0.79	1110 - 2930	7.5 - 18.7	8*
Violaceae	*Viola castillonii* (W. Becker) Xifreda & Sanso(9)		0.79	0.76	2490 - 3510	11.0 - 17.0	8*
Amaryllidaceae	*Zephyranthes diluta* Ravenna (4)			0.70	770 - 4810	5.8 - 27.1	9
Asteraceae	*Baccharis kurtziana* Ariza (6)			0.89	1815 - 3195	6.2 - 11.9	9
Asteraceae	*Baccharis niederleinii* Heering (4)			0.68	1410 - 2230	6.4 - 10.2	9
Asteraceae	*Cabreraea andina* (Cabrera) Bonifacino (5)			0.51	2240 - 3830	6.2 - 12.9	9
Asteraceae	*Flourensia hirta* S.F. Blake (9)			0.70	1660 - 3680	4.8 - 11.0	9
Asteraceae	*Senecio diaguita* Cabrera (8)			0.73	840 - 2665	5.1 - 12.9	9
Asteraceae	*Senecio sanagastae* Cabrera (3)			0.74	1030 - 2780	4.6 - 10.5	9
Asteraceae	*Tagetes riojana* M. Ferraro (4)			0.84	1110 - 2100	8.8 - 12.0	9
Cactaceae	*Lobivia famatimensis* (Speg.) Britton & Rose (4)			0.80	1230 - 2770	4.1 - 16.7	9
Cactaceae	*Pyrrhocactus kattermannii* R. Kiesling (2)			0.71	2100 - 3000	8.81 - 18.58	9

Table 2a. Continued.

Cactaceae	*Tephrocactus alexanderi* (Britton & Rose) Backeb. (11)		0.62	620 - 1960	4.4 - 10.9	9
Fabaceae	*Adesmia hunzikeri* Burkart (5)		0.71	2180 - 3510	5.8 - 8.5	9
Fabaceae	*Adesmia nanolignea* Burkart (8)		0.45	3590 - 4360	5.6 - 10.1	9
Fabaceae	*Senna fabrisii* (L. Bravo) H.S. Irwin & Barneby (7)		0.80	1070 - 2230	4.2 - 8.1	9
Sapindaceae	*Guindilia cristata* (Radlk.) Hunz. (7)		0.64	1460 - 2650	3.1 - 9.3	9
Solanaceae	*Sclerophylax kurtzii* Di Fulvio (19)		0.71	510 - 2765	3.8 - 14.8	9
Solanaceae	*Solanum kurtzianum* Bitter & Wittm. (3)		0.74	1030 - 2780	4.6 - 10.5	9
Amaryllidaceae	*Hieronymiella marginata* (Pax) Hunz. (15)		0.77	1740 - 3620	8.5 - 25.2	10
Anacampserotaceae	*Anacampseros kurtzii* Bacigalupo			3200 - 3800	6.66 - 13.55	10
Apiaceae	*Mulinum famatinense* H. Wolff (6)	0.61	0.66	3180 - 4810	6.2 - 14.8	10
Asteraceae	*Baccharis rupestris* Heering (17)			1310 - 3940	9.1 - 24.2	10
Asteraceae	*Conyza cordata* Kuntze (9)	0.51	0.65	1470 - 3200	11.9 - 28.1	10
Asteraceae	*Chersodoma argentina* Cabrera (24)	0.44	0.43	2830 - 4680	5.0 - 18.1	10
Asteraceae	*Chersodoma glabriuscula* (Cabrera) M.O. Dillon & Sagást. (8)		0.68	2340 - 4320	7.3 - 18.1	10
Asteraceae	*Chuquiraga calchaquina* Cabrera (6)		0.70	2420 - 3450	6.5 - 15.6	10
Asteraceae	*Hieracium streptochaetum* Zahn (8)		0.58	1500 - 4150	9.1 - 26.1	10
Asteraceae	*Hyaloseris rubicunda* Griseb. (21)		0.78	567 - 2530	4.2 - 14.6	10
Asteraceae	*Mutisia kurtzii* R.E. Fr. (29)	0.69	0.69	2750 - 4110	6.9 - 18.5	10
Asteraceae	*Senecio argophylloides* Griseb. (12)		0.75	2770 - 4150	5.1 - 14.8	10
Asteraceae	*Senecio cylindrocephalus* Cabrera (5)		0.72	1250 - 3265	7.9 - 12.2	10
Asteraceae	*Senecio friesii* Cabrera (9)			2505 - 3830	8.4 - 13.0	10
Asteraceae	*Senecio octolepis* Griseb. (21)		0.85	1190 - 3510	7.4 - 19.0	10
Asteraceae	*Senecio pseudotites* Griseb. (8)		0.68	2250 - 3460	9.8 - 18.1	10
Asteraceae	*Senecio schreiteri* Cabrera (8)		0.58	810 - 2550	5.5 - 9.1	10
Brassicaceae	*Draba tucumanensis* O.E. Schulz (6)	0.68	0.70	3000 - 4470	7.3 - 18.6	10
Brassicaceae	*Lepidium argentinum* Thell. (8)	0.74	0.71	1140 - 3510	7.1 - 16.1	10
Bromeliaceae	*Deuterocohnia haumanii* A. Cast. (7)		0.72	1170 - 2010	5.0 - 22.0	10
Cactaceae	*Tephrocactus weberi* (Speg.) Backeb. (11)		0.54	560 - 2050	4.1 - 9.2	10
Cactaceae	*Trichocereus terscheckii* (Parm. ex Pfeiff.) Britton & Rose (23)		0.57	600 - 2720	5.9 - 28.0	10
Caryophyllaceae	*Pycnophyllum convexum* Griseb. (14)	0.61	0.68	3105 - 4610	5.1 - 19.1	10
Euphorbiaceae	*Euphorbia marayensis* Subils (3)			600 - 3500	8.25 - 13.13	10
Ledocarpaceae	*Balbisia calycina* (Griseb.) Hunz. & Ariza (30)		0.89	1530 - 4375	4.8 - 21.2	10
Loasaceae	*Caiophora mollis* (Griseb.) Urb. & Gilg (6)		0.59	2245 - 3960	6.3 - 16.5	10
Nyctaginaceae	*Mirabilis bracteosa* (Griseb.) Heimerl (17)	0.72	0.59	1580 - 4390	6.7 - 22-6	10
Poaceae	*Bromus flexuosus* Planchuelo (12)	0.68	0.62	1850 - 4350	6.9 - 22.1	10
Poaceae	*Jarava scabrifolia* (Torres) Peñailillo (8)		0.65	1070 - 3680	7.0 - 20.6	10
Poaceae	*Nassella caespitosa* Griseb. (29)	0.74	0.65	2270 - 4640	7.5 - 18.1	10
Poaceae	*Panicum chloroleucum* Griseb. (27)	0.80	0.82	1065 - 3500	5.2 - 11.3	10
Poaceae	*Poa dolichophylla* Hack. (19)		0.63	910 - 3180	3.1 - 29.2	10
Poaceae	*Poa hieronymi* Hack. (9)	0.80	0.77	1220 - 2190	8.3 - 28.6	10
Poaceae	*Poa nubensis* Giussani, Fernández Pepi & Morrone (11)			3500 - 4600	6.7 - 16.9	10
Poaceae	*Sporobolus maximus* Hauman (7)	0,72	0,76	1780 - 2950	5,3 - 8,6	10
Polygalaceae	*Polygala argentiniensis* Chodat (10)	0,65	0,68	1410 - 3195	5,5 - 23,4	10
Polygalaceae	*Polygala jujuyensis* Grondona (10)	0,79	0,81	1920 - 4240	5,1 - 15,4	10
Solanaceae	*Fabiana friesii* Dammer (9)		0,78	1730 - 4310	5,6 - 15,9	10

Table 2a. Continued.

Solanaceae	*Jaborosa sativa* (Miers) Hunz. & Barboza (10)			0,47	940 - 3520	3,3 -23,7	10
Solanaceae	*Lycium schreiteri* F.A. Barkley (8)			0,76	1140 - 3200	5,3 - 12,9	10
Solanaceae	*Sclerophylax adnatifolia* Di Fulvio (23)			0,81	1150 - 2900	4,3 - 16,7	10
Solanaceae	*Sclerophylax caducifructus* Di Fulvio (7)			0,77	1620 - 2300	4,3 - 6,8	10
Solanaceae	*Sclerophylax tenuicaulis* Di Fulvio (10)		0,74	0,84	910 - 3290	4,3 - 15,3	10
Solanaceae	*Solanum spegazzinii* Bitter (8)		0,62	0,82	1840 - 4390	6,5 - 11,8	10
Verbenaceae	*Aloysia castellanosii* Moldenke (15)			0,74	670 - 2460	4,0 - 10,6	10
Violaceae	*Viola hieronymi* W. Becker (2)				3040 - 3195	10,9 - 15,1	10
Zygophyllaceae	*Bulnesia schickendantzii* Hieron. ex Griseb. (40)		0,61	0,74	1060 - 3265	4,1 - 19,9	10
Zygophyllaceae	*Plectrocarpa rougesii* Descole, O´Donell & Lourteig (18)		0,77	0,81	970 - 2710	4,0 - 9,6	10
Cactaceae	*Gymnocalycium saglionis* (Cels) Britton & Rose (35)				610 - 2600	6,3 - 29	10
Fabaceae	*Adesmia cytisoides* Griseb. (14)		0,84		1530 - 4100	4,7 - 17,0	10*
Fabaceae	*Hoffmannseggia pumilio* (Griseb.) B.B. Simpson (19)			0,54	1750 - 3500	4,9 - 11.9	10*
Onagraceae	*Oenothera lasiocarpa* Griseb. (8)		0,72		2580 - 4070	9,2 - 17,4	10*
Oxalidaceae	*Oxalis famatinae* R. Knuth (24)		0,61		1670 - 4610	4,2 - 19,1	10*
Poaceae	*Jarava media* (Speg.) Peñailillo (24)		0,71		2102 - 4170	5,1 - 17,0	10*
Amaryllidaceae	*Hieronymiella aurea* Ravenna (5)		0,93	0,73	2260 - 3230	5,9 - 9,2	11
Apocynaceae	*Philibertia subnivea* (Malme) Goyder (1)	0,91	0,88		1880	9,1	11
Asteraceae	*Porophyllum cabrerae* D.J.N. Hind (2)	0,44	0,90		2900 - 3015	8,2 - 9,0	11
Asteraceae	*Verbesina saltensis* Cabrera (1)	0,75	0,88		1720	10,6	11
Boraginaceae	*Ixorhea tschudiana* Fenzl (10)		0,85	0,86	1540 - 1965	6,3 - 9,9	11
Bromeliaceae	*Puya castellanosii* L.B. Sm. (6)	0,60	0,87		2110 - 2930	6,2 - 8,4	11
Bromeliaceae	*Puya weberiana* E. Morren ex Mez (5)		0,89		1650 - 3510	5,9 - 10,5	11
Bromeliaceae	*Tillandsia albertiana* Verv. (1)	0,85	1,00		1160	14,1	11
Cactaceae	*Acanthocalycium thionanthum* (Speg.) Backeb. (11)		0,93		1640 - 3440	5,4 - 9,0	11
Cactaceae	*Gymnocalycium marsoneri* Fric ex Y. Ito (2)		0,82	0,88	810 - 1650	19,0 - 19,9	11
Cactaceae	*Lobivia korethroides* (Werderm.) Werderm. (2)		0,79		3000 - 4200	6,1 - 11,3	11
Cactaceae	*Parodia aureicentra* Backeb. (3)		0,80		2610 - 3230	5,8 - 9,2	11
Cactaceae	*Parodia penicillata* Fechser & Steeg (1)	0,92	1,00		1650	7,0	11
Cactaceae	*Tephrocactus molinensis* (Speg.) Backeb. (3)		0,80		1480 - 2190	6,7 - 9,3	11
Cactaceae	*Trichocereus angelesii* R. Kiesling (2)	0,75	0,82		1640 - 1740	7,8 - 8,3	11
Fabaceae	*Senna rigidicaulis* (Burkart ex L. Bravo) H.S. Irwin & Barneby (2)	0,50	0,88		2220 - 2480	6,8 - 8,4	11
Geraniaceae	*Geranium tafiense* Aedo & Muñoz Garm. (2)		0,80	0, 75	2730 - 2820	9,7 - 12,9	11
Malvaceae	*Nototriche lorentzii* A.W. Hill (1)	0,90	0,90		4150	11,8	11
Solanaceae	*Solanum incurvipilum* Bitter (1)	0,81	0,88		1705	9,6	11
Solanaceae	*Solanum salamancae* Hunz. & Barboza (3)		0,80		1590 - 2820	6,9 - 10,2	11
Asteraceae	*Baccharis petrophila* R.E. Fr. (2)		0,89	0,85	3260 - 3565	8,4	11*
Bromeliaceae	*Tillandsia brealitoensis* L. Hrom. (1)	0,86			2480	6,4	11*
Cactaceae	*Lobivia chrysantha* (Werderm.) Backeb. (2)	0,53	0,90		3260 - 3950	8,1 - 8,7	11*
Cactaceae	*Lobivia walteri* R. Kiesling (1)	1,00			2240	11,5	11*
Cactaceae	*Trichocereus smrzianus* (Backeb.) Backeb. (3)	1,00			3230 - 3540	9,2 - 9,5	11*
Dioscoreaceae	*Dioscorea stenopetala* Hauman (6)		0,74	0,79	1000 - 1820	18,7 - 36,6	11*
Euphorbiaceae	*Euphorbia vervoorstii* Subils (2)		0,83	0,64	740 - 1290	12,5 - 21,7	11*
Orchidaceae	*Pelexia ovatifolia* M.N. Correa (1)		0,75		800	22,1	11*
Poaceae	*Glyceria saltensis* Sulekic & Rúgolo (1)	1,00			3540	9,5	11*

Table 2a. Continued.

Asteraceae	*Senecio fabrisii* Cabrera (2)		0,61	0,68	1720 - 3130	5,8 - 9,7	12
Asteraceae	*Senecio vervoorstii* Cabrera (2)		0,70		2300 - 3370	4,3 - 8,4	12
Cactaceae	*Lobivia haematantha* (Speg.) Britton & Rose (4)		0,74		1900 - 3540	5,7 - 9,0	12
Gentianaceae	*Gentianella pulla* (Griseb.) T.N. Ho & S.W. Liu (5)		0,51		2580 - 3230	9,2 - 15,6	12
Malvaceae	*Tarasa trisecta* (Griseb.) Krapov. (7)		0,66	0,85	1640 - 2900	5,5 - 10,8	12
Oxalidaceae	*Oxalis sleumeri* Lourteig (3)		0,73	0,73	4370 - 5150	11,4 - 19,1	12
Poaceae	*Poa cabreriana* Anton & Ariza (5)		0,46	0,53	1810 - 4645	5,5 - 18,1	12
Solanaceae	*Sclerophylax cocuccii* Di Fulvio (5)		0,86	0,74	1510 - 2900	4,3 - 11,4	12
Amaranthaceae	*Alternanthera cana* Suess. (2)		0,74	0,82	2160 - 2330	5,1 - 6,6	13
Amaranthaceae	*Gomphrena cladotrichoides* Suess. (8)		0,61	0,91	580 - 1590	3,6 - 5,6	13
Asteraceae	*Chuquiraga echegarayi* Hieron. (4)		0,76	0,73	2510 - 3250	9,7 - 15,6	13
Asteraceae	*Senecio calingastensis* Tombesi (2)		0,64	0,86	2890 - 3430	11,7 - 12,2	13
Boraginaceae	*Heliotropium ruiz-lealii* I.M. Johnst. (3)		0,90	0,83	820 - 1070	4,3 - 4,7	13
Brassicaceae	*Descurainia brevifructa* Boelcke ex Mart.-Laborde (1)		0,69	0,72	2940	15,1	13
Cactaceae	*Pterocactus megliolii* R. Kiesling (2)		0,69	0,75	660 - 920	3,7 - 4,4	13
Cactaceae	*Pyrrhocactus sanjuanensis* (Speg.) Backeb. (3)		0,82	0,62	600 - 1330	3,8 - 9,0	13
Cactaceae	*Tephrocactus halophilus* (Speg.) Backeb. (1)				600	4,5	13
Fabaceae	*Prosopis calingastana* Burkart (2)		0,73	0,71	2180 - 2590	8,4 - 8,5	13
Violaceae	*Viola roigii* Rossow (1)		0,69	0,75	2960	15,6	13
Asteraceae	*Senecio belenensis* Griseb. (1)	0,77	0,80		3410	7,3	14
Asteraceae	*Senecio delicatulus* Cabrera & Zardini (2)	0,93	1,00		4090 - 4240	5,5 - 5,7	14
Asteraceae	*Senecio lilloi* Cabrera (1)	0,68	0,88		2600	3,1	14
Cactaceae	*Puna bonniae* D.J. Ferguson & R. Kiesling (1)				2150	4,3	14
Cactaceae	*Tephrocactus geometricus* (A. Cast.) Backeb. (4)		0,80		1645 - 3070	4,1 - 5,3	14
Calceolariaceae	*Calceolaria lepidota* Kraenzl. (1)	0,92	0,90		1810	5,5	14
Caryophyllaceae	*Silene margaritae* Bocquet (1)	0,77	0,80		3410	7,3	14
Malvaceae	*Lecanophora jarae* (Phil.) Krapov. (4)		0,48		3140 - 3690	3,3 - 5,5	14
Malvaceae	*Nototriche chuculaensis* Krapov. (1)	0,75	0,88		4240	5,5	14
Malvaceae	*Nototriche viridula* Krapov. (1)		0,75		3740	7,2	14
Polemoniaceae	*Giliastrum castellanosii* J.M. Porter (2)	0,68	0,88		2600 - 2900	3,1 - 3,3	14
Solanaceae	*Jaborosa cabrerae* Barboza (3)		0,75		2730 - 3420	5,6 - 7,0	14
Amaranthaceae	*Alternanthera cinerella* Suess. (3)	0,65	0,85		1790 - 1800	7,9 - 9,0	15
Apiaceae	*Bowlesia venturii* Mathias & Constance (2)	0,79	0,84		3040 - 3615	12,2 - 14,1	15
Apiaceae	*Eryngium lorentzii* H. Wolff (2)	0,75	0,88	1,00	3040	12,2	15
Apocynaceae	*Cynanchum samuelssonii* Malme (1)	0,76	1,00	1,00	1955	9,6	15
Apocynaceae	*Jobinia glossostelma* (Lillo ex T. Mey.) Liede & Meve (2)		0,81		1420 - 1820	15,7 - 22,0	15
Apocynaceae	*Petalostelma sarcostemma* (Lillo) Liede & Meve (3)		0,54		660 - 975	22,1 - 28,8	15
Aristolochiaceae	*Aristolochia melanoglossa* Speg. (4)		0,70		1610 - 2130	6,3 - 18,6	15
Asteraceae	*Baccharis cabrerae* Ariza (1)	0,92	0,88		2860	7,6	15
Asteraceae	*Baccharis polygama* Ariza (2)	0,92			2885	10,7	15
Asteraceae	*Baccharis rodriguezii* Ariza (2)	0,92	0,88		3250	8,3	15
Asteraceae	*Hieracium cienegae* Zahn (4)	0.93	0.84		2570 - 3040	11.4 - 13.2	15
Asteraceae	*Leptostelma tucumanense* (Cabrera) A. Teles (2)	0.88	0.80	1.00	1740 - 3040	12.2 - 15.0	15
Asteraceae	*Lomanthus calchaquinus* (Cabrera) B. Nord. & Pelser (2)	0.78	0.80		2930 - 3800	11.4 - 14.7	15
Asteraceae	*Microliabum eremophilum* (Cabrera) H. Rob. (1)	0.92	0.88		3250	8.3	15

Table 2a. Continued.

Asteraceae	*Mikania minima* (Baker) B.L. Rob. (2)	0.32	0.87		810 - 1070	15.7 - 19.9	15
Asteraceae	*Mikania siambonensis* Hieron. (1)	0.85	0.80		1300	34.4	15
Asteraceae	*Senecio asplenifolius* Griseb. (3)	0.77	0.83		3720 - 4375	12.3 - 17.8	15
Asteraceae	*Senecio cajonensis* Cabrera (1)	0.81	0.69		4560	13.1	15
Asteraceae	*Senecio kunturinus* Cabrera (2)	0.80	0.81		4460 - 4470	12.9 - 18.6	15
Asteraceae	*Senecio maculatus* Cabrera (2)	0.85	0.82		1650 - 4375	12.4 - 17.8	15
Asteraceae	*Senecio roripifolius* Cabrera (3)	0.78	0.88		3360 - 3710	8.4 - 14.9	15
Asteraceae	*Senecio tucumanensis* Cabrera (2)	0.81	0.92		3510 - 4000	9.3 - 14.6	15
Asteraceae	*Tagetes rupestris* Cabrera (4)	0.76	0.88		1820 - 3810	12.2 - 24.5	15
Begoniaceae	*Begonia tafiensis* Lillo (8)	0.68	0.85		2100 - 3540	11.0 - 15.8	15
Cactaceae	*Acanthocalycium ferrarii* Rausch (2)	0.77	0.92		2320 - 3110	8.3 - 8.6	15
Cactaceae	*Gymnocalycium bayrianum* H. Till (4)		0.69	0.79	890 - 1490	15.2 - 28.4	15
Cactaceae	*Lobivia bruchii* Britton & Rose (4)	0.80	0.74	0.82	2100 - 3180	8.6 - 15.8	15
Cactaceae	*Lobivia schreiteri* A. Cast. (1)	0.74	0.72		1970	18.2	15
Cactaceae	*Trichocereus schickendantzii* (F.A.C. Weber) Britton & Rose (3)	0.39	0.78		1860 - 2170	9.3 - 19.3	15
Caryophyllaceae	*Stellaria aphanantha* Griseb. (1)	0.85			3210	10.1	15
Cyperaceae	*Carex tucumanensis* G.A. Wheeler (1)	0.75	0.88		3040	12.2	15
Dioscoreaceae	*Dioscorea entomophila* Hauman (2)		0.66	0.86	530 - 1740	24.4 - 31.8	15
Fabaceae	*Sophora rhynchocarpa* Griseb. (3)		0.94		930 - 2030	10.5 - 19.6	15
Hypoxidaceae	*Hypoxis catamarcensis* Brackett (1)	0.81	0.71	0.88	1740	15.0	15
Iridaceae	*Mastigostyla johnstoni* R.C. Foster (1)	0.75	0.88		3040	12.2	15
Iridaceae	*Sisyrinchium tucumanum* Ravenna (3)	0.69	0.78		560 - 2560	12.4 - 34.4	15
Loasaceae	*Caiophora aconquijae* Sleumer (6)	0.88	0.86		1710 - 3040	12.2 - 15.7	15
Malvaceae	*Nototriche caesia* A. W. Hill (3)		0.72		3460 - 4440	12.4 - 18.1	15
Malvaceae	*Nototriche cajonensis* Krapov. (2)	0.85			4115 - 4460	10.7 - 12.9	15
Malvaceae	*Nototriche calchaquensis* Krapov. (2)	0.75	0.84		4470 - 4760	18.6 - 21.3	15
Malvaceae	*Nototriche rohmederi* Krapov. (2)	0.91	0.80		4420 - 4760	17.8 - 21.3	15
Malvaceae	*Nototriche tucumana* Krapov. (1)	0.86			4375	17.8	15
Montiaceae	*Schreiteria macrocarpa* (Speg.) Carolin (1)	0.86			2445	10.4	15
Onagraceae	*Oenothera pedunculifolia* W. Dietr. (4)		0.89		830 -2500	9.7 - 34.5	15
Orchidaceae	*Chloraea castillonii* Hauman (3)	0.77	0.92		2110 - 3045	6.9 - 12.2	15
Orchidaceae	*Chloraea phoenicea* Speg. (2)	0.68	0.88	0.86	3230 - 3640	9.1 - 11.2	15
Plantaginaceae	*Plantago venturii* Pilg. (3)	0.48	0.77		1260 - 3040	12.2 - 19.7	15
Poaceae	*Nassella fabrisii* Torres (6)		0.72		990 - 3180	12.2 - 32.4	15
Poaceae	*Nassella leptothera* (Speg.) Torres (3)	0.52	0.79		1880 - 2940	9.1 - 11.3	15
Ranunculaceae	*Ranunculus hilii* Lourteig (4)	0.66	0.81		1660 - 1840	15.0 - 26.4	15
Rosaceae	*Lachemilla grisebachiana* (L.M. Perry) Rothm. (1)	0.83		0.72	2700	13.3	15
Solanaceae	*Cestrum kunthii* Francey (8)		0.76		940 - 1960	9.6 - 34.0	15
Solanaceae	*Eriolarynx iochromoides* (Hunz.) Hunz. (3)	0.77	0.86		1510 - 1600	15.7 - 29.2	15
Solanaceae	*Eriolarynx lorentzii* (Dammer) Hunz. (8)	0.42	0.77		1280 - 1940	14.2 - 34.4	15
Solanaceae	*Jaborosa oxipetala* Speg. (3)		0.84		690 - 1960	15.4 - 25.3	15
Solanaceae	*Solanum sanctae-rosae* Hawkes (5)	0.77	0.83		2840 - 3220	9.1 - 12.5	15
Valerianaceae	*Valeriana lasiocarpa* Griseb. (2)	0.85	0.75		3210 - 3720	10.1 - 14.7	15
Violaceae	*Viola calchaquiensis* W. Becker (1)	0.81			4375	17.8	15
Violaceae	*Viola lilloana* W. Becker (2)	0.69	0.77		4190 - 4515	11.8 - 12.7	15

Table 2a. Continued.

Violaceae	*Viola munozensis* W. Becker (1)	0.81	0.88		4300	17.3	15
Violaceae	*Viola rodriguezii* W. Becker (4)	0.67	0.82		3000 - 4560	10.5 - 17.8	15
Violaceae	*Viola tucumanensis* W. Becker (2)	0.81	0.85		3400 - 3480	12.2 - 13.3	15
Acanthaceae	*Justicia hunzikeri* Ariza (5)				560 - 1080	9.0 - 16.0	16
Cactaceae	*Gymnocalycium castellanosii* Backeb. (15)				400 - 1100	8.9 - 15.9	16
Fabaceae	*Ramorinoa girolae* Speg. (6)				800 - 1275	6.4 - 13.7	16
Poaceae	*Neobouteloua paucirracemosa* M.G. López & Biurrun (4)				310 - 750	12.6 - 15.7	16
Amaryllidaceae	*Chlidanthus yaviensis* (Ravenna) Ravenna (1)	0.74	0.79		3460	15.7	17
Asteraceae	*Antennaria sleumeri* Cabrera (1)	0.57			1800	24.3	17
Asteraceae	*Hieracium neofurcatum* Sleumer (2)	0.62	0.73		3220 - 3940	16.8 - 17.9	17
Asteraceae	*Stevia okadae* Cabrera (1)	0.92			3685	16.5	17
Asteraceae	*Vernonia centauropsidea* Hieron. (3)	0.75	0.75		1660 - 1850	23.4 - 25.1	17
Bromeliaceae	*Puya yakespala* A. Cast. (3)	0.92	0.73		3280 - 3940	16.6 - 16.8	17
Cactaceae	*Lobivia chrysochete* (Werderm.) Wessner (1)	0.71	0.73		3480	17.4	17
Cactaceae	*Lobivia sanguiniflora* Backeb. (1)	0.81	0.73		3610	15.8	17
Cactaceae	*Rebutia margarethae* Rausch (1)	0.86	0.73		3940	16.8	17
Gentianaceae	*Gentianella cabrerae* (Fabris) Fabris (1)	0.92			2990	18.1	17
Iridaceae	*Mastigostyla brachiandra* Ravenna (1)	0.86	0.73		3280	16.6	17
Iridaceae	*Mastigostyla implicata* Ravenna (1)	0.74	0.73		3540	15.5	17
Malvaceae	*Nototriche sleumeri* Krapov. (2)	0.82		0.83	4150 - 4410	15.9 - 16.5	17
Poaceae	*Danthonia rugoloana* Sulekic (1)	0.71	0.79		3680	15.6	17
Poaceae	*Nassella yaviensis* Torres (1)	0.74	0.73		3540	15.5	17
Solanaceae	*Solanum neorossii* Hawkes & Hjert. (2)	0.78	0.73		3520	17.0	17
Tropaeolaceae	*Tropaeolum atrocapillare* Sparre (2)	0.60	0.73		2610 - 3030	17.1 - 18.4	17
Amaryllidaceae	*Habranthus ruizlealii* Ravenna (1)				280	14.5	?
Asteraceae	*Chiliotrichiopsis keidelii* Cabrera (39)				2490 - 4620	6.8 - 17.4	?
Asteraceae	*Eupatorium saltense* Hieron. (31)				1310 - 2590	16.0 - 35.0	?
Asteraceae	*Eupatorium tucumanense* Lillo & B.L. Rob. (11)				560 - 1720	22.4 - 31.7	?
Asteraceae	*Flourensia leptopoda* S.F. Blake (4)				410 -2420	6.5 - 15.0	?
Asteraceae	*Stevia minor* Griseb. (21)				2940 - 4250	5.2 - 18.6	?
Brassicaceae	*Descurainia adpressa* Boelcke (6)				3480 - 4820	7.6 - 15.9	?
Cactaceae	*Gymnocalycium ragonesei* A. Cast. (1)				180	15.3	?
Cyperaceae	*Carex humahuacaensis* G.A. Wheeler (2)				3705 - 4030	4.4 - 10.6	?
Fabaceae	*Adesmia crassicaulis* Phil. (4)				3040 - 4375	3.4 - 21.3	?
Fabaceae	*Astragalus crypticus* I.M. Johnst. (8)				2960 - 4375	7.8 - 17.8	?
Gentianaceae	*Gentianella punensis* (Fabris) Fabris (1)				4250	4.3	?
Poaceae	*Festuca nemoralis* Türpe (14)				830 - 4090	12.2 - 34.5	?
Poaceae	*Festuca parodiana* (St.-Yves ex Parodi) Nicora (15)				1000 - 2870	6.1 - 36.6	?
Poaceae	*Jarava hystricina* (Speg.) Peñailillo (10)				2815 - 4210	5.1 - 12.9	?
Poaceae	*Nassella glabripoda* Torres (11)				1050 - 4100	6.9 - 19.0	?
Poaceae	*Nassella meyeri* Torres (9)				2410 - 3705	6.2 - 12.8	?
Poaceae	*Pappostipa hieronymusii* (Pilg.) (4)				2470 - 4480	2.8 - 8.9	?
Solanaceae	*Jaborosa lanigera* (Phil.) Hunz. & Barboza (9)				3510 - 4680	5.7 - 10.4	?
Solanaceae	*Solanum annuum* C.V. Morton (10)				2310 - 3685	7.7 - 16.5	?
Violaceae	*Viola evae* Hieron. ex W. Becker (2)				4070 - 4170	3.9 - 14.8	?

Table 2b. Code of area names used in Table 2a.

Area number	Area	Fig.
1	Ambato	4M
2	Andes La Rioja-San Juan	4F
3	South Bolivia-north NOA	4I
4	Bolivian Prepuna	4J
5	Catamarca and La Rioja, summits and dry inner valleys	4P
6	Famatina	4H
6*	Famatina, border	4H
7	Jujuy, core	4C
7*	Jujuy, border	4C
7**	Jujuy, core and border	4C
8	Jujuy-Tucumán, core	4E
8*	Jujuy-Tucumán	4E
9	La Rioja and San Juan, summits and dry inner valleys	4Q
10	NOA	4B
10*	NOA (San Juan)	4B
11	Salta, core	4L
11*	Salta	4L
12	Salta-Catamarca, summits and dry inner valleys	4O
13	San Juan	4G
14	Tinogasta - Belén	4N
15	Tucumán	4D
16	Valle Fértil	4R
17	Yavi-Santa Victoria	4K

ed in a phytogeographic scheme developed by Cabrera (1951, 1953, 1976) and Cabrera & Willink (1973 - see Fig. 1) that is widely used by South American biologists, as well as by governmental and non-governmental organizations (Ribichich, 2002). The study region includes xerophytic Chaco vegetation in north-eastern lowlands, and arid Monte vegetation in the south-eastern lowlands. Subtropical moist broadleaf forests, locally known as Yungas, are found at the eastern slopes north of 28º S. The Andes vegetation is furthermore divided in Puna vegetation between approx. 3500m-4500m above which extends the high Andean grasslands that reaches the line of *perpetual snow*. The Prepuna province - which is the only phytogeographic unit confined to the study region – extends north-south through the region on the dry mountain slopes approx. between 2400 m and 3500 m asl (Fig.1 and 2B). The present study follows the phytogeographic scheme of Cabrera (1951, 1953, 1976), and that of Ibisch et al. (2003) for the Yungas forests. Ibisch et al. (2003) recognized the north-south oriented Yungas forests that are found within our study region as the Tucumano-Bolivian Yungas. Due to differences in temperature, precipitation seasonality, and taxonomic composition the Tucumano-Bolivian Yungas were considered a phytogeographic unit distinct from the more tropical northwest-southeast oriented Bolivian-Peruvian Yungas forests found north of the Andes bend (~18ºS).

Data set

According to the catalogue of the Southern Cone flora (Zuloaga et al., 2008) 589 species of vascular plants are strictly endemic to the Argentinean portion of the study region which is approx. 1/3 of the species endemic to Argentina in general (Zuloaga et al., 1999). We compiled the distribution of 513 endemic species excluding 40 species that were only known from localities that could not be georeferenced with precision, while 36 species were excluded as they were found outside the study region while we were compiling their distribution. In addition to species endemic to north-western Argentina we added 27 species endemic to the Bolivian Prepuna or shared between the Bolivian Prepuna and north-western Argentina. These species were selected with assistance from Dr. Beck (the National Herbarium, La Paz, Bolivia) as a checklist of vascular plants of Bolivia has not been completed yet. All endemic species as well as author names are found in Table 2.

Species distribution were compiled from collections deposited in the herbaria BA, BAA, LIL, LP, LPB, and SI. We considered a species sufficiently sampled when the distribution data reflected the distribution published in the Catalogue of the Plants of the Southern Cone (Zuloaga et al., 2008). Redundant locations were only georeferenced if the collections differed sufficiently in altitude to suggest that the species appears in several phytogeographic strata. To facilitate the task of georeferencing, specimens with altitude noted in the field by the collector were preferred. If the herbarium vouchers were not sufficient to cover the published distributions we added published exsiccatae from the original descriptions or monographies. Finally we used the Missouri Botanical Garden data base TROPICOS® (http://www.tropicos.org) to complete distribution data or to exclude species collected outside the study region.

Distribution data without corresponding vouchers deposited in public herbaria were only used for some Bolivian endemics, where we added field observations from R. P. López, and also when compiling species distribution within the Cactaceae. The Cactaceae are particularly species rich in the study region (Mourelle & Ezcurra, 1996) but also one of the most underrepresented families in herbaria; as a result, specimens deposited in public herbaria are far from covering the distribution of an individual species. Since the Cactaceae is one of the main targets for commercial collectors the information on collection sites, found at Cactus-enthusiastic homepages, is overwhelming and in sharp contrast with the sparse information available from traditional academical sources. We choose to include information from a private collector homepage (http://ralph.cs.cf.ac.uk/Cacti/finder.html). This procedure was done after consulting a specialist on the family, Dr. Roberto Kiesling, in order to avoid species that are not easily recognized in the field. Data from this source were also considered only when the location, and altitude, agrees with the distribution range defined in the Catalogue of the Plants of the Southern Cone (Zuloaga et al., 2008).

A total of 3262 records were compiled and georeferenced. This gives an unimpressive average of six registers/species, which both reflect that species were not georeferenced, in the study, for redundant or proximate locations, and that endemic species of north-western Argentina and southern Bolivia are usually rare and poorly collected, many of them being only known from the type material.

All specimens without GPS recorded coordinates were georeferenced according to the point-radius method of Wieczorek et al. (2004). We carefully respected the altitudes of the collection sites in order to extract climate data with as much accuracy as possible. All data have been submitted to the online version of Flora Argentina (http://www.floraargentina.edu.ar).

Analyses

We searched for areas of endemism using the program NDM/VNDM ver. 2.7c (Goloboff, 2005). VNDM is a grid based method that identifies an area of endemism as the congruent distributions of two or more species (Szumik et al., 2002; Szumik and Goloboff, 2004, 2007). The general outputs in VNDM are area sets (groups of cells in the grid) that are supported by the presence of two or more species. Each area receives an endemism-score according to the optimality criterion developed for the method. The optimality criterion measures the 'fit' of each species to the area, e.g. how well each species found within the area adjust to this. The optimality criterion penalizes both absence in part of the area as well as presence in adjacent cells outside the area (if a species is present outside the area in a non-adjacent cell it is not considered among the species supporting the area). The endemism score for each area is the sum of the 'fit' of the supporting species. The endemism score is therefore influenced both by the number of species supporting an area as well as the distribution of the supporting species within and around the area (Szumik et al., 2002; Szumik and Goloboff, 2004).

The algorithms in NDM have lately been found to outperform other and more widespread methods for delimiting areas of endemism such as hierarchical clustering (Carine et al., 2008; Escalante et al., 2009). One of the advantages of NDM is its ability to recognize overlapping distribution patterns if these are defined by different species groups. Overlapping patterns may be independent if defined by different sets of species (Szumik & Goloboff, 2004), and are to be expected when distribution analysis are based on grids if more than one environments are found in the same cell.

Grid and cell size

As discussed by Linder (2001) the choice of grid size is important. The use of small cells would result in a finer and more detailed resolution but at the same time increase the number of artificially empty cells where species occur but have not been recorded. We used three different cell sizes to explore both distribution patterns at different scale as well as the robustness of the resulting areas to changes in grid size (Aagesen et al., 2009; Navarro et al., 2009). Grids with cell sizes 0.2ºx0.2º, 0.5ºx0.5º, and 0.5ºx-1.0º were used where 1º is approximately equal to 100 km. In the last grid we used rectangular cells rather than square cells because the north-south running Andes Mountains form a steep east-west altitude gradient that causes various habitat changes within 100 km. The rectangular cells were used to explore north-south running patterns of widely distributed but poorly collected species without lumping too many habitats into the same cell.

Fill option

The problem of artificial empty cells is some-

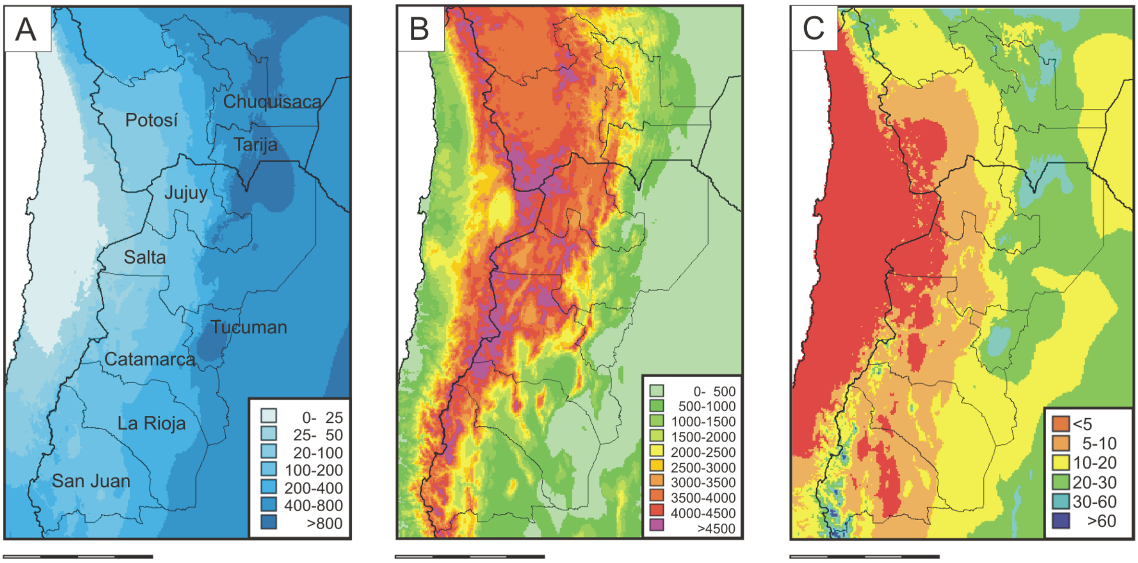

Fig. 2. **A,** annual precipitaton in mm. **B,** altitude (m asl) in the study region. **C,** map of de Martonne aridity index. Scale bars = 400 km. Color version at http://www.ojs.darwin.edu.ar/index.php/darwiniana/article/view/435/462

what alleviated in NDM by a user defined fill option (radius size) that assumes the presence of a given species if it has been collected close to the limit within a neighbouring cell (Szumik & Goloboff, 2004; Aagesen et al., 2009; Escalante et al., 2009). We used two radius sizes (see Table 1). The smallest radius size reflects approximately the error of the hand georeferenced records as determined by the point-radius method (Wieczorek et al., 2004; see Aagesen et al., 2009) while the second and wider radius size was used to explore dependence on the fill options in the final areas of endemism.

Search procedure

The searches were done using default settings with the following changes: swap two cells at a time; discard superfluous sets as they are found; replace a set if improved during swapping; precheck duplicates; keep overlapping subsets if 20% of species unique. Searches were done by changing the seed for each search, without replacing existing sets and deleting duplicate sets after each replicate. This search sequence was repeated until numbers of sets were stable.

Consensus rules

As we kept all overlapping subsets if they differed by 20% in species composition, we found several area sets that were supported by 5-20 species but differing only by one or two species. Area sets can be merged into consensus areas if they share at least some of their defining species (Szumik & Goloboff, 2007). Two consensus rules are available in VNDM. The strictest consensus rule merges area sets if they all share a user defined percentages of their defining species – (in the program called 'against every included area' hereafter abbreviated as consensus rule ae). The second more relaxed criterion includes an area set in a consensus if it shares a user defined percentage of its defining species with at least one other area set in the consensus – (called 'against any included area' hereafter abbreviated as consensus rule aa; see Aagesen et al., 2009).

Ideally, the strict consensus rule ae should be used for identifying areas of endemism as at least some species are shared among all the individual area sets, thus ensuring a certain coherency within the area. Consensus areas derived from the laxer consensus rule aa, are efficient to outline gradual species overlap between area set, but the distribution of the species defining the consensus are likely to be found in just a small part of this. However, due to the high number of ae consensus produced by our data (Table 1) it was unfeasible to base the discussion on the ae consensus areas only. Consequently, we explored areas of endemism through

Table 3. Areas separating from main consensus in Fig. 4, ordered according to max. area score (grid size 0.5º x 0.5º). The areas were obtained by gradually increasing consensus criterion from 5% to 50% (ae and aa refer to different consensus rules).

Area	Obtained under 0.2º x 0.2º	Nr. of sub-sets in consensus	Area score	Nr. of Families/ Genera/ Species	Altitude range	Aridity range	Fig.	Separates from main area
Jujuy -core and border	yes	101	2.1-26.3	31/66/87	350-5100	6.2-33.7	4C	40% aa
Tucumán	yes	17	7.3-23.3	22/38/55	530-4800	6.3-34.5	4D	45% aa
Salta	yes	36	2.7-13.3	14/23/27	740-4200	5.4-36.6	4L	50% aa
Famatina	yes	2	10.9-13.1	8/10/19	1150-4100	4.5-15.0	4H	25% aa
Famatina border		1	3.9-4.2	2/2/6	750-2200	7.2-11.8		25% aa
Yavi-Santa Victoira	yes	2	10.6-10.8	8/12/13	1700-4400	15.5-25.1	4K	25% aa
Jujuy-Tucumán	yes	370	2.0-10.4	38/59/85	350-5000	5.2-40.4	4E	50% aa
Ambato	yes	24	2.4-10.3	11/14/22	1000-3700	6.6-18.1	4M	45% aa
Bolivian Prepuna	yes	19	2.2-6.5	11/16/21	1400-4400	6.7-26.3	4J	25% aa
Tinogasta-Belén	yes	9	2.6-4.5	7/8/11	1600-4300	3.1-7.3	4N	45% aa
San Juan	no	8	2.0-3.8	7/10/10	850-3400	3.6-15.6	4G	not part of main area
Catamarca-La Rioja summits and dry inner valleys	no	19	2.0-3.8	12/14/19	500-4500	4.8-18.6	4P	30% aa
NOA	no	14	2.0-3.5	10/19/20	560-4800	3.1-29.2	4B	not part of main area
NOA-San Juan		2	2.1-2.4	4/4/4	150-4600	4.7-19.1		not part of main area
South Bolivia-north NOA	no	1	3.0-3.2	4/4/2	2000-4000	6.6-19.6	4I	not part of main area
Andes La Rioja-San Juan	no	6	2.1-2.8	8/10/11	1000-4500	3.8-24.1	4F	not part of main area
Salta-Catamarca summits and dry inner valleys	no	4	2.1-2.8	7/7/8	1500-5100	4.3-19.1	4O	45% aa

the laxer aa rule that produced less, and more inclusive consensus areas.

Environmental data and aridity

Environmental data for the study region that includes both Argentina and Bolivia is limited to the data available in WorldClim (Hijmans et al., 2005). We used the program Diva-Gis 7.4.0.1 (Hijmans et al., 2005-2010) to extract altitude, temperature, and precipitation of the collection sites. As the collection sites span from 500 m asl to 5000 m asl and an annual mean temperature from -3ºC to 23ºC we used humidity rather than rainfall when comparing different sites. We adopted the aridity index of De Martonne (1927) that can be calculated through the limited environmental variables available for the study region, and furthermore provides a quantitative measure for the useful but somewhat imprecise terms arid, semi-arid, humid, etc.

Aridity Index of de Martonne. Accumulated annual precipitation / (annual mean temperature + 10). We use the following categories (De Martonne, 1927; Almorox, 2003): 0-5: desert; 5-10: semi desert; 10-20: semi arid; 20-30: subhumid; 30-60: humid; >60: wet. Distribution of aridity within the study region is shown in Fig. 2C.

RESULTS

The results are summarized in Table 1-3. In general, the number of area sets increased with cell size, but the bigger cells also produced more overlapping distribution patterns that grouped into fewer consensus areas under the laxer aa rule (Table 1). The two different fill radius produced nearly identical results in number of area sets and consensus areas, hence support for the resulting areas did not depend on a specific fill ratio. The discussion is based on the analyses using the widest fill ratios.

Five hundred-nineteen (519) species supported some area under at least one grid size, while 21 species did not support any area (Table 2). Of these, eight species are only known from a single or two localities, while the remaining species are widely distributed within the region.

The study region has been sufficiently sampled to analyse species distribution under cell sizes 0.5ºx0.5º where most cells of the study region are assigned to one or more areas of endemism (Fig. 3A). When the cell size is reduced to 0.2ºx0.2º only the cores of the main areas are recovered even if presence of one or more endemic species is recorded in most cells (Fig. 3B). Consequently, we base our discussion on the results from analysing cells of 0.5ºx0.5º. The two alternative cell sizes with either smaller or longer cells were only used to explore the distributions of species that did not support distribution patterns under the 0.5ºx0.5º grid.

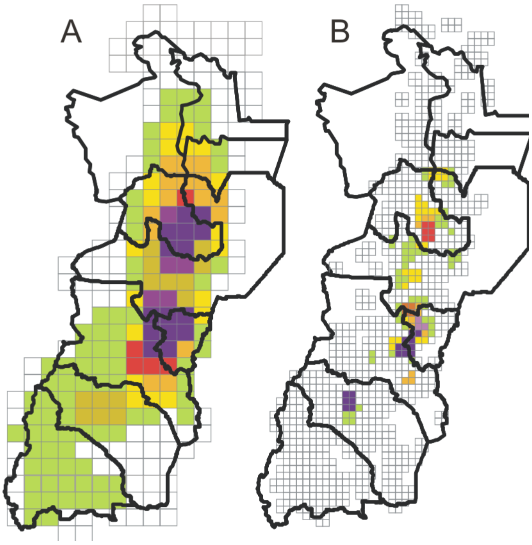

Fig. 3. Areas of endemism and sample density of endemic species. Empty cells: presence of one or more endemic species in the cell. Colour filled cells: cell assigned to one or more areas of endemism. The colour scale represents areas of endemism of higher (darker) versus lower (lighter) endemism score. A, grid size 0.5ºx0.5º. B, grid size 0.2ºx0.2º. Color version at http://www.ojs.darwin.edu.ar/index.php/darwiniana/article/view/435/462

When using a grid size of 0.5ºx0.5º, the lax aa consensus rule produced seven distribution patterns, under both the 5% and 10% consensus criterion (Table 1). About 2/3 of the endemic species were gathered in a single main consensus area (Fig. 4A), while five distinct distributions, with a total of 49 species, did not form part of the main pattern (see discussion below). A single area consisting of four species was considered an artefact and not discussed any further (the species from this pattern are considered part of the complex Jujuy-Tucumán area, see Discussion and Appendix). The remaining 120 endemic species did not support any area under this grid size.

In order to explore sub-areas of the main consensus area in Fig. 4. A this was decomposed by gradually increasing the consensus criterion. By this procedure sub-areas separate successively from the main area with those defined by less overlapping species separating first. We decomposed the main area both to extract the individual high endemic areas as well as to assign all endemic species to sub-areas with a closer association between area extension and distributions of the defining species (see, Consensus rules). All final sub-areas (Table 3, Fig. 4) are also found under the strictest ae consensus rule.

A total of 17 areas of endemism are discussed below. The 120 species that did not support areas in the 0.5ºx0.5º grid were assigned to one of these 17 areas according to results found under the 0.2ºx0.2º or 0.5ºx1.0º grids (Table 2). Two areas are based exclusively on results obtained by analysing cells sizes of 0.5ºx1.0º; these areas were not found under the smaller cell sizes. Only 21 species did not support any of the final areas.

We have named areas of endemism according to the political division in which the core of the area occurs. The political names do not indicate that the areas fit any political border or that the political borders have influenced the analysis. The names are simply useful for a quick spatial orientation. In some cases, such as Famatina and Ambato, the political names coincide with the mountain range in which the endemic species from the core areas have been found. In other cases such as Jujuy and Tucumán several mountain ranges and valleys are included in the core of the areas with some of these situated in the neighbouring province Salta.

Even when subdividing the main area into sub-areas, most of the defining species will be distributed only in part of the area. One example is *Aphelandra lilacina* that has only been collected in ‘El Rey’ National Park in the province of Salta. The cell including ‘El Rey’ National Park lies in the south easternmost low endemic part of the Jujuy border area (Fig. 4C). Consigning *Aphelandra lilacina* to the Jujuy area is therefore slightly misleading, but a necessity unless a prohibited high number of consensus areas are shown. However, as our aim is to provide an overview of the distribution of the endemic species in north-western Argentina we concentrate the discussion on main distribution patterns. Further details of the individual species distribution can be consulted in the online version of the Flora Argentina (http://www.floraargentina.edu.ar) that includes dot distribution maps and label information for all specimens included in the present study.

Table 4. Main radiations within the study region. Only families with 10 or more endemic species, and genera with five or more species have been included. For the families, the percentage of the total number of endemic species within the region is shown.

Main families: nr. of endemic species	Main genera: nr. of endemic species
Asteraceae: 126 (23%)	*Senecio*: 39 *Hieracium*: 10 *Flourensia*: 9 *Baccharis*: 8 *Stevia*: 6
Cactaceae: 75 (14%)	*Lobivia*: 16 *Gymnocalycium*: 15 *Trichocereus*: 13 *Parodia*: 7 *Tephrocactus*: 6
Poaceae: 46 (8%)	*Nassella*: 12 *Poa*: 6
Fabaceae: 34 (6%)	*Lupinus*: 10 *Adesmia*: 8 *Astragalus*: 8
Solanaceae: 29 (5%)	*Solanum*: 18 *Sclerophylax*: 6
Malvaceae: 25 (5%)	*Nototriche*:19
Bromeliaceae: 17 (3%)	*Puya*: 9
Apocynaceae: 15 (3%)	*Philibertia*: 8
Violaceae: 12 (2%)	*Viola*: 12
Gentianaceae: 11 (2%)	*Gentianella*: 11

DISCUSSION

The vast majority of the vascular flora endemic to the southern part of the central Andes outlines small, successively overlapping sub-areas that combine into a single main consensus area only under the lax consensus rule and a very lax consensus criterion (Fig. 4A). Endemism is far from evenly distributed among the sub-areas but declines gradually towards the south and west of the study region. Peaks of endemism are found near the humid Andes slopes in Jujuy, Tucumán/Ambato, and to a lesser extent in the isolated Sierra de Famatina in La Rioja.

Although the main portion of the endemic species conform to the patchy distribution patterns that

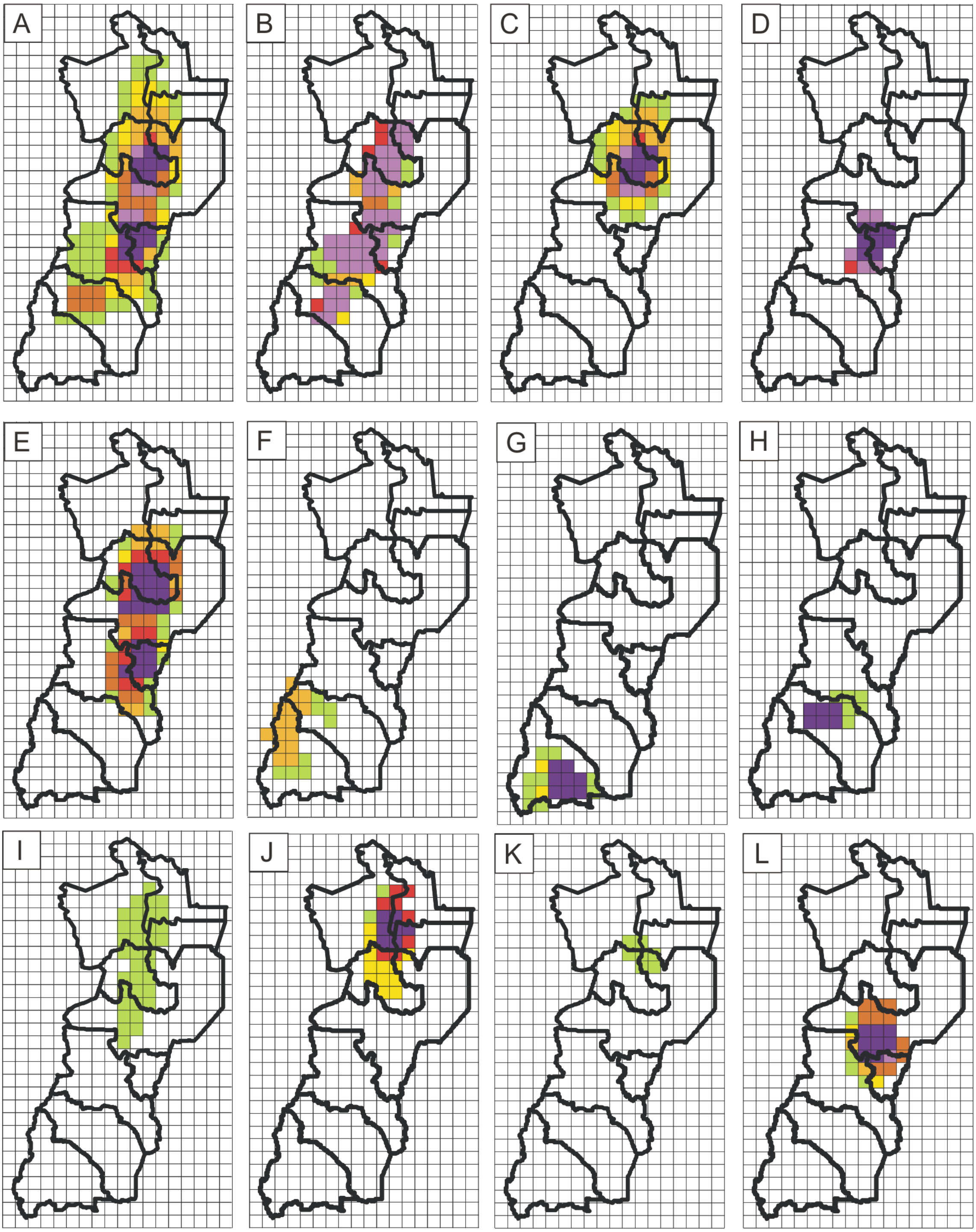

Fig. 4. A-L. Areas of endemism discussed in the text and in Appendix 1. The colour scale represents cells of higher (darker) versus lower (lighter) endemism score within each area. The colour scale is scaled to show max details of endemism within each area. For max and min score within the individual areas see Table 3. **A,** main consensus. **B,** NOA. **C,** Jujuy, core and border. **D,** Tucumán. **E,** Jujuy-Tucumán. **F,** La Rioja-San Juan Andes. **G,** San Juan. **H,** Famatina. **I,** South Bolivia-north NOA. **J,** Bolivian Prepuna. **K,** Yavi-Santa Victoria. **L,** Salta core and border.

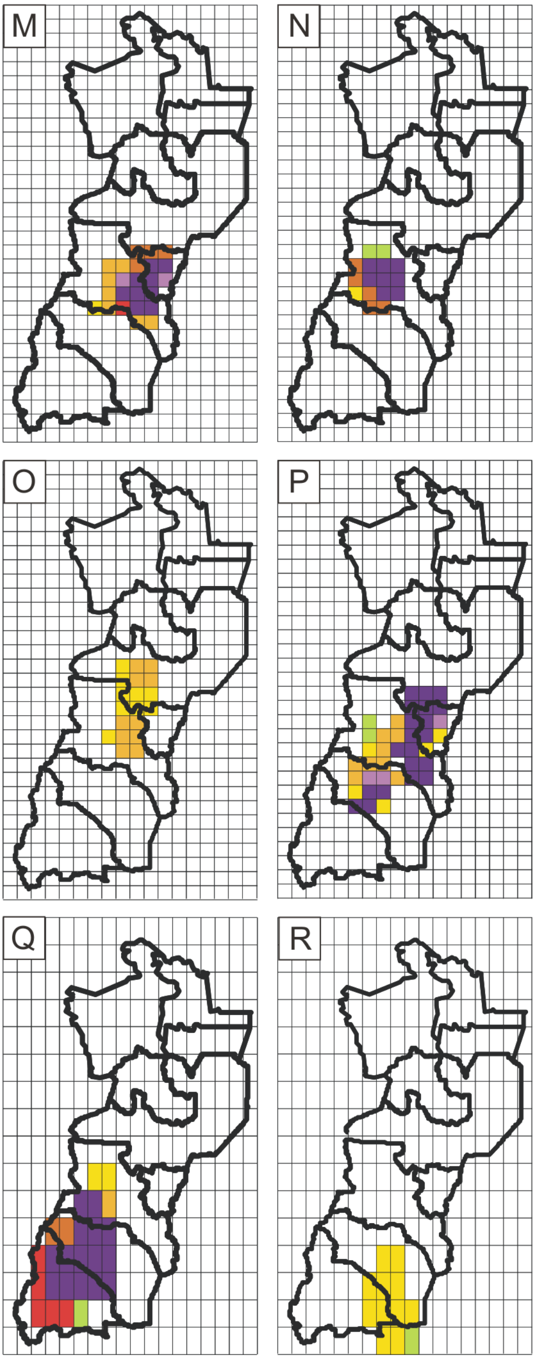

Fig. 4. Continued. **J-R. J,** Bolivian Prepuna. **K,** Yavi-Santa Victoria. **L,** Salta core and border. **M,** Ambato. **N,** Tinogasta-Belén. **O,** Salta-Catamarca. **P,** Catamarca-La Rioja. **Q,** La Rioja-San Juan. **R,** Valle Fertil. Color version at http://www.ojs.darwin.edu.ar/index.php/darwiniana/article/view/435/462

form the consensus in Fig. 4A, the southern part of the central Andes can still be recognized as a single area of endemism, defined by at least 53 species that are widely distributed within the region (the NOA area in Fig. 4B).

Here we discuss taxonomic composition and habitat of the endemic species from the study region in general, as well as the individual main distribution areas such as the general NOA pattern and sub-areas of the main consensus in Fig. 4A. Sub-areas were separated from the main consensus by gradually raising the consensus criterions, which causes sub-areas to separate successively. A total of 18 different sub-areas were identified (Table 2-3) among which we discuss selected high-endemic areas. A description of the remaining areas is found in Appendix 1.

Altitude and Aridity

Our results indicate that 473 of the endemic species, nearly 90%, have been collected at middle altitudes between 1500-3500 m asl (Table 2), a pattern that is consistent with the notion that Prepuna slope vegetation harbours the main part of the endemic species. Only 40 species are restricted to altitudes below 1500 m asl while 33 species are restricted to high Andean environments above 4000 m asl (mainly from the genera *Senecio* L., *Nototriche* Turcz., and *Viola* L.). The relative low number of endemic high Andean species is perhaps unexpected and may be underestimated as collection of high Andean localities above 4000 m asl are sparse. However, part of the high Andean flora were left out of the analyses as it is shared with the neighbouring Chile.

In accordance with the general arid climate of the central Andes, the semi-arid environments (AI=10-20, Fig. 2C) appear as the principal habitat type for the endemic species. Semi-arid environments harbour about 80% of the endemic flora with 30% (159 species) being restricted to this habitat type. Semi-arid environment are mostly extended at lower altitudes (compare Fig. 1 and 2A), but only 14 endemic species are restricted to altitudes below 1000 m asl (Table 2). Consequently the relatively narrow band of semiarid habitats between 1500-3500 m asl (compare Fig. 2 B and C) includes the main portion of the endemic species, making the topographic complex plateau, slope, and valley system of the southern central Andes the main locations for endemism.

As few as 36 species are restricted to subhumid or humid environments (AI=20-60, Fig. 2C) indicating that the diverse Tucumano-Bolivian Yungas forest is surprisingly poor in endemic species at a local scale. This is in accordance with Ibisch et al. (2003) who considered the endemism of the Tucumano-Bolivian Yungas to be unimportant at a local Bolivian scale and moderate at the inclusive scale considering the Tucumano-Bolivian Yungas forests in their entire extension. The Bolivian-Peruvian Yungas forests were in contrast considered the main area of endemism for Bolivia. Endemism in the south-western Bolivia were, as in the present study, mainly found in the Prepuna vegetation and in the arid interandean forests (Ibisch et al., 2003). In this study the mountain grasslands above the tree line are rich in local endemics [note that these grasslands were considered the highest strata of the Yungas by Cabrera (1976), while we follow Ibisch et al. (2003) who included these grasslands in the subhumid Puna restricting the term Tucumano-Bolivian Yungas to forest vegetation].

Local endemics are also nearly lacking from desert environments with only seven species found exclusively in habitats with an aridity index below 5 (Table 2). Although desert environments are found throughout the study region, they become part of the distribution pattern only in the areas that include patches of desert climate separated from the Andes (i.e. in the Catamarca, La Rioja, and San Juan provinces – Table 3, Fig. 2C). Only a single species, *Gentianella punensis*, is collected above 3500 m asl where it is endemic to vegas in the deserts of northern Salta. Dry adapted endemic desert species are consequently restricted to desert parches of middle or low altitudes, such as the inner basins of the Andes that are covered by Monte vegetation. High Andean desert environments are common on both sites of the Andes in the northern part of the study region (compare Fig. 2 B and C), hence desert endemics may be lacking from the northern areas because the endemic species are shared between Argentina and Chile, hence excluded from our analyses.

Taxonomic groups

The Asteraceae outnumbers all other families in the region, with 121 endemic species from 35 genera (Table 2 and 4); furthermore, it is the only family with endemic species supporting all areas (except Valle Fértil - Fig. 4R). The endemic Asteraceae are found in all environments ranging from species restricted to humid habitat (e.g., *Mikania siambonensis* and *Vernonia novarae*), to desert environment (e.g., *Senecio lilloi*), and from strict high Andean (e.g., *Senecio kunturinus* and *S. delicatulus*) to lowland species (e.g. *Eupatorium tucumanense* and *Isostigma molfinianum*).

Nearly 1/3 of the endemic Asteraceae belong to the genus *Senecio* with 39 endemic species in the study region – twice as many species as the second most common genera *Lobivia* Britton & Rose (Cactaceae), *Nototriche* (Malvaceae), and *Solanum* L. (Solanaceae) (see Table 4). Nonetheless, the remaining 2/3 of the endemic Asteraceae are highly diverse belonging to 16 of approx. 48 Asteraceae tribes (Funk et al., 2009), the most numerous being the Astereae Cass., Eupatorieae Cass., and Heliantheae Cass. including 17, 13, and 10 species each.

Although both the origin and early diversification of the Asteraceae are likely to have occurred in southern South America (Funk et al., 2009) the main radiations of Asteraceae within the study region belong to clades that are principally found in the northern hemisphere, e.g., *Senecio*, *Hieracium* L., *Flourensia* DC., *Baccharis* L., and *Stevia* Cav. (see Funk et al., 2009 for biogeography of the family). Still, all tribes from the basal Asteraceae grade (Mutisieae s. l. sensu Cabrera; Ortiz et. al. 2009) are represented, although in lower numbers, among the local endemic species, with Hyalideae Panero being the only exception. The Asteraceae endemics are consequently not only numerous within the region but also phylogenetically diverse, both reflecting the general family trend of being especially diverse in arid environments (Funk et al., 2009) as well as the fact that the Asteraceae is the most diverse family both in number of genera and species within the southern cone (Zuloaga et al., 1999; Moreira-Muñoz & Muñoz-Schick, 2007).

Cactaceae is the second most numerous family with 74 endemic species and 15 genera within the study region (Table 3). Unlike the Asteraceae the main part of the endemic Cactaceae belong to a single clade (55 species), the tribe Trichocereeae Buxb. that principally consists of high Andean species from the eastern slopes of the central Andes (Ritz et al., 2007, Hernández-Hernández et al., 2011). The remaining Cactaceae species are either close relatives to the Trichocereeae from the Core Cactoideae II clade that also includes the Trichocereeae (Hernández-Hernández et al., 2011) or from early diverging lines of the subfamily Opuntioideae (Griffith & Portery, 2009).

Like the Asteraceae, the Cactaceae are considered to be of South American origin with the early diversification of the tribes Trichocereeae and Opuntioideae situated in the Central Andes (Nyffeler, 2002; Edwards et al., 2005; Griffith & Porter 2009). While the extreme succulence of most Cactaceae species makes the family well adapted to the aridity of the southern central Andes, the Cactaceae endemics occupy nearly as wide an array of habitats as the Asteraceae including strict Altoandine species restricted to altitudes above 4000 m (*Lobivia marsoneri*), with endemic species only lacking from the most humid part of the study region.

Following Asteraceae, Poaceae is the second most diverse family in the southern cone (Zuloaga et al., 1999) and reaches the study region as the third most numerous family with 45 endemic species from 20 different genera (Table 3). The endemic species belong to both of the main Poaceae clades, the BEP and the PACMAD clades (GPWG 2001; Sánchez-Ken et al., 2007; GPWG II, 2012). The BEP clade generally appears in colder climates than the PACMAD clade (Edwards & Smith, 2010), and it is more species rich in the study region, with 34 endemic species versus 11 from the PACMAD.

Like Asteraceae, the endemic Poaceae species are found in most of the available habitat types (see Table 2) with two species restricted to subhumid or humid environments (*Aristida pedroensis* and *Chusquea deficiens*), high Andean species restricted to altitudes above 4000 m asl (*Anatherostipa henrardiana* and *Poa nubensis*) and lowland species only found below 1000 m asl (e.g., *Digitaria catamarcensis* and *Neobouteloua paucirracemosa*). Only strict desert endemics are lacking although a single species from semi-desert environments enter desert habitats (*Pappostipa hieronymusii*).

In addition to the main families discussed above, the Solanaceae and Malvaceae both include genera with considerable radiations within the region. The genus *Solanum* with 18 endemic species occupies a wide array of habitats from semi-arid to humid environments between 500 and 4000 m asl. Several of the *Solanum* endemics reach sub-humid and humid sites, with four of the species restricted to these habitats, while desert environments are occupied by another Solanaceae genus, *Sclerophylax* Miers with six endemic species in the region (Table 2).

As opposed to the taxa mentioned above, the radiation of *Nototriche* (Malvaceae) is exclusively high Andean, with all 19 endemic species found in semi-desert to semi-arid environments above 4000 m asl. Other well documented high Andean radiations such as *Gentianella* Moench, *Lupinus* L., and *Valeriana* L. (von Hagen & Kadereit, 2001; Bell & Donoghue, 2005; Hughes & Eastwood, 2006) are less important in the region with eleven, seven, and five endemic species, all found at lower altitudes than *Nototriche*.

Main areas of endemism

The NOA (Nor-Oeste-Argentina) area. The NOA area (Fig. 4B) is the general area of endemism for the southern part of the central Andes. The area is supported by species that are widely distributed within the study region and overlaps with all below mentioned sub-areas segregated from the main consensus in Fig. 4A. Four species reach the south of San Juan (Table 2) and consequently define a slightly wider pattern than the NOA area shown in Fig. 4B.

The northern limit of the NOA area coincides with the political border between Argentina and Bolivia hence the pattern probably extends into southern Bolivia. However, the scarcity of intensive botanical explorations in this part of Bolivia prevents us to speculate on the exact northern limit of the NOA pattern. So far among the defining NOA species only *Mirabilis bracteosa*, *Mutisia kurtzii*, and *Trichocereus terscheckii* have been collected in Bolivia, but endemic Argentinean taxa widely distributed in Jujuy are most probably also present in southern Bolivia.

Since the distribution pattern spans approximately 1000 km from north to south, the pattern is unsurprisingly not recovered when using cell sizes of 0.2ºx0.2º, a feature that requires collection sites every 20 to 40 km depending on the settings of the fill option (see Material and Methods). The NOA pattern emerges when using cell sizes of 0.5ºx0.5º in which case 24 species are sufficiently well collected to define the area (Table 2). Other common, but less frequently collected species such as the columnar cactus *Trichocereus terscheckii*, support the north-south running pattern when the grid is changed to a cell size of 0.5ºx1.0º, allowing for even wider distances between the collecting sites. A total of 54 species support the area when using a cell size of 0.5ºx1.0º (Table 2).

All NOA endemics are found in desert, semi-desert and semi-arid habitats with several species also reaching either desert or sub-humid sites. Humid environments are not part of the pattern, which is consistent with the north-southern range of the area, e.g. the distributions of the defining species that reach out of the region where the humid habitats are found. Consequently, the moist requiring species are restricted to the northern portion of the study region and support sub-areas in Fig. 4A but not the general NOA pattern. The broader distribution pattern reaching San Juan is slightly dryer and does not include sub-humid habitats.

The NOA pattern includes all altitudinal layers of the vegetation as the defining species are found from 500 m to above 4500 m asl. However, slopes vegetation seem to be an important part of the distribution pattern as all species appear between 1500 m and 3500 m asl. Most species have broad ranges with some ranging nearly 3000 m asl (e.g. *Oxalis famatinae* see Table 2). The highest part of the NOA pattern is defined by species restricted to high Andean vegetation above 3000 m asl (e.g., *Mulinum famatinense* and *Pycnophyllum convexum*). The lowest part of the distribution pattern includes several plants that are common to Monte vegetation (Cabrera, 1976) and is delimited by *Tephrocactus weberi* that is found between 500-2000 m asl in desert and semi-desert habitats.

Several of the species that define the NOA pattern are common elements in the vegetation of the study region. These include the bushes *Bulnesia schickendantzii*, *Plectocarpa rougesii* (Zygophyllaceae), *Mutisia kurtzii*, and *Cersodoma argentina* (Asteraceae), as well as the grasses *Panicum chloroleucum* and *Sporobolus maximus*. Common but less frequently collected species that support the north-south running pattern when the grid is changed to cell size 0.5ºx1.0º, include the columnar cactus *Trichocereus terscheckii*, the opuntioid cactus *Tephrocactus weberi*, the cushion forming Bromeliaceae *Deuterocohnia haumanii* and *Hieronymiella marginata* (Amaryllidaceae) (Table 2).

High endemic areas: Jujuy, Tucumán, and Jujuy-Tucumán. Within the study region, the cells of highest endemism score include the cores of the Jujuy area, the Tucumán area, and the combined Jujuy-Tucumán area (Fig. 4C-E). These three areas are jointly supported by nearly 30% of the endemic species found in the region, and are furthermore by far the most diverse both in number of genera and families (Table 2). When also considering the species that define the diffuse border of the core areas (Fig. 4C, Table 2), about 45% of the endemic species are confined to these three distribution patterns that undoubtedly form the main area of endemism in the southern cone east of the Andes.

Common for the cores of both the Jujuy and Tucumán areas are that they include some of the study regions most variable cells both in terms of altitude, temperature, and precipitation. The available habitats within these areas range through all phytogeographic unites described for north-western Argentina (Cabrera, 1976). While variability in temperature and altitude do not decline along the north-south gradient of the study region, amount of rainfall does decline (Fig. 2A). Humid sites with an aridity index above 30 are mainly found at the eastern Andean slopes in both the Jujuy and Tucumán areas (Fig. 2C). Consequently, endemic species from humid environments, such as the subtropical Tucumano-Bolivian Yungas forests are only found in the three high endemic areas (Table 2). Nevertheless, and although the Tucumano-Bolivian Yungas forest is one of the most diverse phytogeographic units in Argentina (Cabrera, 1976; Zuloaga et al., 1999), it should be noted that only twelve species are restricted to humid sites in the present study (Table 2), indicating that the Yungas vegetation includes few endemic species at this local scale. The main part of the endemic species are distributed through the broad array of available habitats both in terms of altitude and aridity (Table 3), with no species occupying the entire range (Table 2).Variability in precipitation rather than high rainfall might therefore be the main factor that causes high level of endemism within the Jujuy and Tucumán areas.

The decline in endemism in the center of the Jujuy-Tucumán area is consistent with the patterns found in general diversity studies (Szumik et al., 2012), and distribution maps of the Yungas forest (Hawkes & Hjerting, 1969; Cabrera, 1976; Brown, 1995). It is unclear whether the decline in diversity and endemism is caused by lack of collections or whether some habitats - e.g., humid high Andean grasslands - are lacking in this part of the area.

Minor areas of endemism: San Juan, Famatina, and south-western Bolivia. Several minor areas of endemism separate from the general area consensus in Fig. 4A. Here we discuss two southern most areas in San Juan, the central Famatina area, as well as an area related to the vegetation in south-western Bolivia. The full list of areas is found in Appendix 1.

San Juan: Two areas of endemism are defined by species restricted to the southern most part of the study region, the Andes of La Rioja-San Juan (Fig. 4F) and the San Juan area (Fig. 4G, Table 2). These two areas are well defined and do not combine with the general consensus area even under very lax consensus criteria, hence the areas do not share species with any of the other areas of endemism. This distinct distribution pattern of the endemic species from the southern part of the study region may reflect that the San Juan areas lie close to the limit of the Patagonian phytogeographic unit sensu Cabrera (1976), hence close to a general change in vegetation types that is widely recognized among biogeographers (e.g., Olson et al. 2001; Morrone, 2006). The San Juan areas are among the most arid areas within the study region. Although some of the species that define the Andes area of La Rioja-San Juan (Fig. 4F) reach sub-humid locations according to Table 2, these sub-humid locations fall at sites where the annual mean temperature is below 0º C rather than at sites with high rainfall (note that for the same annual precipitation the aridity index of de Martonne will increase with falling mean annual temperature).

Famatina. The Famatina areas both separate from the main area when raising the consensus criterion to 25% (Fig. 4H). The two partly overlapping areas include a highly endemic area of species found mainly above 1500 m asl as well as a low endemic border area of species found at lower altitudes. The areas do not share species, hence, these areas do not combine into a single consensus area. Combined both Famatina areas are supported by 28 endemic species found in desert/semi-desert and semi-arid environments between 700 m and 4000 m asl.

The area with highest endemism score contains primarily the isolated Nevados de Famatina that reaches above 6000 m asl. Mining activity at 4.600 m asl has ensured long standing accessibility to the high peaks where botanical exploration has been relatively constant since the late 19th century. The Famatina is, consequently, one of the best sampled high Andean locations south of the high-endemic areas in Jujuy and Tucumán. Nonetheless, Famatina is defined by much less endemic species than the areas Jujuy and Tucumán. Furthermore, diversity within this area is low as more than half of the endemic species belong to three of the most species rich radiations within the study region: *Senecio*, *Nototriche* at altitudes above 3000 m asl, and *Gymnocalycium* Pfeiff. ex Mittler in the border area (Fig. 4H) below 2000 m asl.

South-western Bolivia-northern Argentina. Towards the northern part of the study region four species delimit a shared, well defined Bolivian-Argentinean area that do not combine with any other distribution pattern even under very lax consensus criteria (Fig. 4I, Table 2-3). The area overlaps partly with the NOA pattern (Fig. 4B) but stretches further north into Bolivia. The Bolivian portion of this area corresponds to the Bolivian Prepuna as defined by López (2000) while the Argentinean part only includes the northern most part of the Prepuna province sensu Cabrera (1976). The area defined in Fig. 4I includes semi-desert and semi-arid habitats between 200-4000 m. When increasing the cell size to 0.5ºx1.0º two additional species (*Deuterocohnia strobilifera* and *Oxalis cotagaitensis*) are incorporated into the area.

Although only six species support the Bolivian-Argentinean area, our study did not sample exhaustively this region, therefore it is most likely that other species share a similar distribution pattern. According to the Catalogue of the Plants of the Southern Cone (Zuloaga et al., 2008) at least 70 species are distributed from Salta to Bolivia many of which may approximately fit the area in Fig. 4I. This distribution pattern stresses the similarity between the flora of southern Bolivia and north-western Argentina as mentioned by López (2000, 2003), but further sampling within the region is needed to establish the size and importance of the area.

The Bolivian Prepuna, sensu López (2000), is nested within the above south-western Bolivia-northern Argentina distribution pattern but combined with the main distribution pattern shown in Fig. 4A. The Bolivian Prepuna segregates from the main area in Fig. 4A when the consensus criterion is raised to 25% or higher (Fig. 4J). The Bolivian Prepuna is formed by two overlapping distribution patterns one of which enters northern Jujuy (Argentina). Both patterns are supported by species that are mainly found in semi-arid environments from 2500 m up to 4000 m asl with the highest collection sites lying in the Argentinean side of the pattern. Since we did not compile an exhaustive list of species endemic to southern Bolivia, the Bolivian Prepuna may also be supported by more species that those included in our study.

Phytogeographic divisions: the Prepuna province and areas of endemism

Although Cabrera aimed to base his classic phytogeographic scheme on the presence of endemic taxa from family to species level (Cabrera 1951, 1953, 1976), the system was not based on quantitative studies and did not apply consistent criteria for defining the individual phytogeographic units (Ribichich, 2002). It is therefore not surprising that quantitative analyses, based on endemic species distribution, result in areas of endemism that do not correspond to Cabrera's phytogeographic divisions. In our analyses all areas were defined by species from a wide array of altitudes in most cases including lowland, slopes, and high Andean species (Table 2). Moreover, as the areas with highest endemism were found in regions where several climatic regimes meet (Jujuy and Tucumán), they include several phytogeographic units within shortest distances of each other. As a result, the species that define the high endemic areas are just as variable as the areas themselves in their altitude and aridity ranges (Table 2).

Cabrera (1976) defined the Prepuna province as xeric slope vegetation with emphasis on the distribution of emblematic species such as columnar cacti and cushion forming Bromeliaceae species, mentioning several species from different families as common on the slopes. López (2000, 2003) later extended the Prepuna to include a similar xeric vegetation in the south-western Bolivia. The Prepuna, which is here included in its entire extension, does not appear among the resulting areas of endemism, hence the Prepuna province sensu Cabrera (1976) is not definable simply by the presence of two or more unique Prepuna species.

The partly overlapping south-western Bolivia/northern NOA and the NOA area (Figs. 7 and 12) cover geographically the Prepuna in its entire extension. Both areas are defined by several of Cabrera's (1976) Prepuna species including columnar cacti and cushion forming *Deuterocohnia* Mez species. Notably three of the species mentioned by Cabrera: *Aphylloclados spartioides*, *Cercidium andicola*, and *Prosopis ferox* define the joint Southern-Bolivia/northern NOA (Fig. 4I) supporting the northern Prepuna as delimited by López (2000, 2003) in which the Bolivian Prepuna separates as an independent area of endemism (Fig. 4J). Columnar *Trichocereus* (A. Berger) Riccob. species define both the Bolivian Prepuna and the NOA area while most of Cabrera's (1976) remaining Prepuna species support the NOA area. The NOA distribution pattern does, however, also include species from other altitude strata, hence, although it appears to include the Prepuna it defines a broader area of endemism in the southern central Andes.

CONCLUSIONS

Located in the center of the South American dry diagonal, the aridity of southern central Andes is reflected in the distribution of its endemic vascular flora. Of 540 endemic plant species, more than 2/3 are restricted to semi-desert and semi-arid habitats including some of these regions main radiations, such as the ultra high Andean *Nototriche* (Malvaceae) and the radiation of *Gymnocalycium* (Cactaceae) found below 2000 m. Even the 39 endemic species from the cosmopolitan genus *Senecio* (Asteraceae) are almost exclusively found in semi-desert or semi-arid habitats with only two species entering subhumid or humid locations.

The distributional bias of the endemic species towards arid sites is in contrast with that of vascular plant diversity in the region, since the Tucumano-Bolivian Yungas forests, on the humid eastern Andes slopes, undoubtedly include the most diverse vegetation of the region (Brown, 1995; Ibisch et al., 2003). The Tucumano-Bolivian Yungas forests in north-western Argentina are, however, a patch of a more extensive area of endemism whose northern limit is found south of the Andes bend at approx. 18ºS (Ibisch et al., 2003). Emblematic Yungas species, such as *Juglans australis* Griseb., *Podocarpus parlatorei* Pilg, and *Duranta serratifolia* (Griseb.) Kuntze appear to be endemic to the Tucomano-Bolivian Yungas. Other species such as *Alnus acuminata* Kunth and *Fuchsia boliviana* Carrière are widely distributed along the eastern slopes and further north to Mexico. These forests may consist of several nested or partly overlapping distribution patterns as is the case of the endemic vegetation of the arid slopes of the southern central Andes. Any attempt to evaluate endemism of the Tucomano-Bolivian Yungas should include these forests in their entire extension.

Although the Yungas forests are of little importance for endemisms at the scale of our study, the high endemic areas of the region lies in juxtaposition, west of the main rainfall zones (Fig 1a). The endemic species of these areas are found in a broad and variable range of aridity and altitude (Table 2), hence, rather than high rainfall itself, the gradual decreasing rain-veil west of the main rainfall zone caused by the complex topography of the region, may be the main factor allowing for the elevated number of endemic species to coexist in these areas.

We did not find any relationship between the main areas of endemism and phytogeographic units previously defined, as the main areas of endemism appeared in cells that included a widest array of habitats. The Prepuna province sensu Cabrera (1976) and López (2000, 2003) was not defined by the endemic species as a unit; instead, two partly overlapping areas covered the entire extension of the Prepuna (Figs. 6 and 14). Both areas include several Prepuna characteristics sensu Cabrera (1976). Nevertheless, of these two areas, the NOA area should be considered a general area of endemism for the southern central Andes since it also included high Andean and lowland species.

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BIBLIOGRAPHY

Aagesen, L.; C. A. Szumik; F. O. Zuloaga & O. Morrone. 2009. Quantitative biogeography in the South America highlands – recognizing the Altoandina, Puna and Prepuna through the study of Poaceae. *Cladistics* 25: 295-310.

Almorox, J. 2003. Climatología aplicada al medioambiente y Agricultura. Monografía del Depto. de Edafología. Madrid: Universidad Politécnica de Madrid.

Arroyo, M. T. K.; R. Rozzi; J. A. Simonetti; P. Marquet & M. Salaberry. 1999. Central Chile, en R. A. Mittermeier, N. Myers, P. Robles Gil & C. Goettsch Mittermeier (eds.), *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecorregions*, pp. 161-171. México: CEMEX.

Arroyo, M. T. K.; P. Marquet; C. Marticorena; J. Simonetti; L. A. Cavieres; F. A. Squeo & R. Rozzi. 2004. Chilean winter rainfall - Valdivian forests, en R. A. Mittermeier, P. Robles, M. Hoffmann, J. Pilgrim, T. Brooks, C. Goettsch-Mittermeier, J. Lamoreux & G. A. B. da Fonseca (eds.), *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*, pp. 99-103. México: CEMEX.

Bannister, J. R.; O. J. Vidal, E. Teneb & V. Sandoval. 2012. Latitudinal patterns and regionalization of plant diversity along a 4270-km gradient in continental Chile. *Austral Ecology* 37: 500-509.

Bell, C. D. & M. J. Donoghue. 2005. Phylogeny and biogeography of Valerianaceae (Dipsacales) with special reference to the South American valerians. *Organism, Diversity & Evolution* 5: 147-159.

Bianchi, A. R. & S. C. Cravero. 2010. *Atlas climático digital de la República Argentina*. Salta: Instituto Nacional de Tecnología Agropecuaria.

Brown, A. D. 1995. Fitogeografía y conservación de las selvas de montaña del noroeste de Argentina, en S. P. Churchill, H. Balslev, E. Forero & J. L. Luteyn (eds.), *Biodiversity and Conservation of Neotropical Montane Forests*, pp. 663-672. New York: The New York Botanical Garden.

Cabrera, A. L. 1951. Territorios fitogeográficos de la República Argentina. *Boletín de la Sociedad Argentina de Botánica* 4: 21–65.

Cabrera, A. L. 1953. Esquema fitogeográfico de la República Argentina. *Revista del Museo Eva Perón, Botánica* 8: 87–168.

Cabrera, A. L. 1976. Regiones fitogeográficas argentinas. *Enciclopedia Argentina de Agricultura y Jardinería*, vol. 2, parte 1. Buenos Aires: ACME.

Cabrera, A. L. & A. W. Willink. 1973. Biogeografía de América Latina. *Serie de Biología OEA. Monografía* 13: 1–117.

Carine, M. A.; C. J. Humphries, I. R. Guma, J. A. Reyes-Betancort & A. Santos Guerra. 2008. Areas and algorithms: evaluating numerical approaches for the delimitation of areas of endemism in the Canary Islands archipelago. *Journal of Biogeography* 36: 593-611.

Crisp, M.; S. Laffan, H. P. Linder & A. Monro. 2001. Endemism in the Australian flora. *Journal of Biogeography* 28: 183–198.

de Martonne, E. 1927. Regions of interior-basin drainage. *Geographical Review* 17: 397-414.

Edwards, E. J.; R. Nyffeler & M. J. Donoghue. 2005. Basal cactus phylogeny: implicactions of *Pereskia* (Cactaceae) paraphyly for the transition to the cactus life form. *American Journal of Botany* 92: 1177-1188.

Edwards, E. J. & S. A. Smith. 2010. Phylogenetic analyses reveal the shady history of C_4 grasses. *Proceedings of the National Academy of Sciences* 107: 2535-2537.

Escalante, T.; C. A. Szumik & J. J. Morrone. 2009. Areas of endemism of Mexican mammals: reanalysis applying the optimality criterion. *Biological Journal of the Linnean Society* 98: 468-478.

Funk, V. A.; A. A. Anderberg, B. G. Baldwin, R. J. Bayer, M. Bonifacino, I. Breitwieser, L. Brouillet, R. Carbajal, R. Chan, A. X. P. Coutinho, D. J. Crawford, J. V. Crisci, M.

O. Dillon, S. E. Freire, M. Galbany-Casals, N. Garcia-Jacas, B. Gemeinholzer, M. Gruenstaeudl, H. V. Hansen, S. Himmelreich, J. W. Kadereit, M. Källersjö, V. Karaman-Castro, P. O. Karis, L. Katinas, S. Keeley, N. Kilian, R. T. Kimball, T. K. Lowrey, J. Lundberg, R. J. McKenzie, T. Mesfin, M. E. Mort, B. Nordenstam, C. Oberprieler, S. Ortiz, P. B. Pelser, C. P. Randle, H. Robinson, N. Roque, G. Sancho, J. C. Semple, M. Serrano, T. F. Stuessy, A. Susanna, M. Unwin, L. Urbatsch, E. Urtubey, J. Vallès, R. Vogt, S. Wagstaff, J. Ward & L. E. Watson 2009. Compositae metatrees: the next generation, en V. A. Funk, A. Susanna, T. F. Stuessy & R. Bayer (eds.), *Systematics, evolution and biogeography of the Compositae*, pp. 747-777. Vienna: International Association for Plant Taxonomy.

Goloboff, P. 2004. NDM/VMDM, programs for identification of areas of endemism. Program and documentation. Available at http://www.zmuc.dk/public/phylogeny/endemism.

Grass Phylogeny Working Group. 2001. Phylogeny and subfamilial classification of the grasses (Poaceae). *Annals of the Missouri Botanical Garden* 88: 373–457.

Grass Phylogeny Working Group II. 2012. New grass phylogeny resolves deep evolutionary relationships and discovers C4 origins. *New Phytologist* 193: 304–312.

Griffith, M. P. & J. M. Porter. 2009. Phylogeny of Opuntioideae (Cactaceae). *International Journal of Plant Sciences* 170**:** 107-116.

Hawkes, J. G. & J. P. Hjerting. 1969. *The potatoes of Argentina, Brazil, Paraguay, and Uruguay – a biosystematic study*. Oxford: Clarendon Press.

Hernández-Hernández, T.; H. M. Hernández, J. A. De-Nova, R. Puente, L. E. Eguiarte & S. Magallón. 2011. Phylogenetic relationships and evolution of growth form in Cactaceae (Caryophyllales, Eudicotyledoneae). *American Journal of Botany* 98**:** 44-61.

Hijmans, R. J.; S. E. Cameron, J. L. Parra, P. G. Jones & A. Jarvis. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965-1978.

Hijmans, R. J.; L. Guarino, A. Jarvis, R. O'Brien, P. Mathur, C. Bussink, M. Cruz, I. Barrantes & E. Rojas. 2005-2010. DIVA-GIS, manual and program http://www.diva-gis.org

Hughes, C. & R. Eastwood. 2006. Island radiation on a continental scale: exceptional rates of plant diversification after uplift of the Andes. *Proceedings of the National Academy of Sciences* 103: 10334-10339.

Ibisch, P.L.; S.G. Beck, B. Gerkmann & A. Carretero. 2003. La diversidad biológica: ecorregiones y ecosistemas, en P. L. Ibisch & G. Mérida (eds.), *Biodiversidad: La Riqueza de Bolivia*, pp. 47-88. Santa Cruz de la Sierra: Editorial Fundación Amigos de la Naturaleza (FAN).

Kier, G.; J. Mutke, E. Dinerstein, T. H. Ricketts, W. Küper, H. Kreft & W. Barthlott. 2005. Global patterns of plant diversity and floristic knowledge. *Journal of Biogeography* 32: 1107–1116.

Linder, H. P. 2001. Plant diversity and endemism in sub-Saharan tropical Africa. *Journal of Biogeography* 28: 169-182.

López, R. P. 2000. La prepuna boliviana. *Ecología en Bolivia* 34: 45-70.

López, R. P. 2003. Diversidad florística y endemismo de los valles secos bolivianos. *Ecología en Bolivia* 38: 27-60.

López, R. P. & S. Beck. 2002. Phytogeographical affinities and life form composition of the Bolivian Prepuna. *Candollea* 57: 77-96.

López, R. P.; D. L. Alcázar & M. J. Macía. 2006. The arid and dry plant formations of South America and their floristic connections: new data, new interpretation? *Darwiniana* 44: 18-31.

Montecinos, A. & P. Aceituno. 2003. Seasonality of the ENSO-related rainfall variability in central Chile and associated circulation anomalies. *Journal of Climate* 16: 281-296.

Moreira-Muñoz, A. & M. Muñoz-Schick. 2007. Classification, diversity, and distribution of Chilean Asteraceae: implications for biogeography and conservation. *Diversity and Distributions* 13: 818-828.

Morrone, J. J. 2001. *Biogeografía de América Latina y el Caribe,* vol. 3, 148 pp. Zaragoza: SEA.

Morrone, J. J. 2006. Biogeographic areas and transition zones of Latin America and the Caribbean Islands based on panbiogeographic and cladistic analyses of the entomofauna. *Annual Review of Entomology* 51: 467-494.

Mourelle, C. & E. Ezcurra. 1996. Species richness of Argentine cacti: a test of biogeographic hypotheses. *Journal of Vegetation Science* 7: 667-680.

Navarro, F. R.; F. Cuezzo, P. A. Goloboff, C. Szumik, M. Lizarralde de Grosso & G. Quintana. 2009. Can insect data be used to infer areas of endemism? An example from the Yungas of Argentina. *Revista Chilena de Historia Natural* 82: 507-522.

Nyffeler, R. 2002. Phylogenetic relationships in the Cactus family (Cactaceae) based on evidence from *trnK*/*matK* and *trnL-trnF* sequences. *American Journal of Botany* 89: 312-326.

Olson, D. M.; E. Dinerstein, E. D. Wikramanayak, N. D. Burgess, G. V. N. Powell, E. C. Underwood, J. A. D'Amico, I. Itoua, H. E. Strand, J. C. Morrison, C. J. Loucks, T. F. Allnutt, T. H. Ricketts, Y. Kura, J. F. Lamoreux, W. W. Wettengel, P. Hedao & K. R. Kassem. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth. *BioScience* 51: 933-938.

Orme, C. D. L.; R. G. Davies, M. Burgess, F. Eigenbrod, N. Pickup, V. A. Olson, A. J. Webster, T.-S. Ding, P. C. Rasmussen, R. S. Ridgely, A. J. Stattersfield, P. M. Bennett, T. M. Blackburn, K. J. Gaston & I. P. F. Owens. 2005. Global hotspots of species richness are not congruent with endemism or threat. *Nature* 436: 1016-1019.

Ortiz, S.; M. Bonifacino, J. V. Crisci, V. A. Funk, H. V. Hansen, D. J. N. Hind, L. Katinas, N. Roque, G. Sancho, A. Susanna & C. Tellería. 2009. The basal grade of Compositae: Mutisieae (sensu Cabera) and Carduoideae, en V. A. Funk, A. Susanna, T. F. Stuessy & R. Bayer (eds.), *Systematics, evolution and biogeography of the Compositae*, pp. 193-213. Vienna: International Association for Plant Taxonomy.

Ribichich, A. M. 2002. El modelo clásico de la fitogeografía de Argentina: un análisis crítico. *Interciencia* 27: 669-675

Ritz, C. M.; L. Martins, R. Mecklenburg, V. Goremykin & F. H. Hellwig. 2007. The molecular phylogeny of *Rebutia* (Cactaceae) and its allies demonstrates the influence of paleogeography on the evolution of South American mountain cacti. *American Journal of Botany* 94: 1321–1332.

Rodriguez-Cabral, M. A.; M. A. Nuñez & A. S. Martínez. 2008. Quantity versus quality: endemism and protected areas in the temperate forest of South America. *Austral Ecology* 33: 730-736.

Sánchez-Ken, J. G.; L. G. Clark, E. A. Kellogg & E. E. Kay. 2007. Reinstatement and emendation of Subfamily Micrairoideae (Poaceae). *Systematic Botany* 32: 71-80.

Simpson, B. B. & C. A. Todzia. 1990. Pattern and processes in the development of the high Andean flora. *American Journal of Botany* 77: 1419-1432.

Skelnář, P.; E. Dušková & H. Balslev. 2011. Tropical and Temperate: Evolutionary history of Páramo flora. *Botanical Review* 77: 71-108.

Szumik, C.; L. Aagesen, D. Casagranda, V. Arzamendia, D. Baldo, L. E. Claps, F. Cuezzo, J. M. Díaz Gómez, A. Di Giacomo, A. Giraudo, P. Goloboff, C. Gramajo, C. Kopuchian, S. Kretzschmar, M. Lizarralde, A. Molina, M. Mollerach, F. Navarro, S. Nomdedeu, A. Panizza, V. V. Pereyra, M. Sandoval, G. Scrocchi & F. O. Zuloaga. 2012. Detecting areas of endemism with a taxonomically diverse data set: plants, mammals, reptiles, amphibians, birds, and insects from Argentina. *Cladistics*. 28: 317–329.

Szumik, C.; F. Cuezzo, P. A. Goloboff & A. Chalup. 2002. An optimality criterion to determine areas of endemism. *Systematic Biology* 51: 806–816.

Szumik, C. & P. A. Goloboff. 2004. Areas of endemism: an improved optimality criterion. *Systematic Biology* 53: 973–980.

Szumik, C. & P. A. Goloboff. 2007. NDM/VNDM: Computer programs to indentify areas of endemism. *Biogeografía* 2: 32-37.

von Hagen, K. B. & J. W. Kadereit. 2001. The phylogeny of *Gentianella* (Gentianaceae) and its colonization of the southern hemisphere as revealed by nuclear and chloroplast DNA sequence variation. *Organism, Diversity & Evolution* 1: 61-79.

Wieczorek, J.; Q. Guo & R. J. Hijmans. 2004. The point-radius method for georeferencing locality descriptions and calculation associated uncertainty. *International Journal of Geographical Information Science* 18: 745–767.

Zhou, J. & K. M. Lau. 1998. Does a monsoon climate exist over South America? *Journal of Climate* 11: 1020-1040.

Zuloaga, F. O.; O. Morrone & D. Rodríguez. 1999. Análisis de la biodiversidad en plantas vasculares de la Argentina. *Kurtziana* 27: 17-167.

Zuloaga, F.O.; O. Morrone and M. J. Belgrano. 2008. Catálogo de las Plantas Vasculares del Cono Sur. *Monographs in Systematic Botany from the Missouri Botanical Garden* 107: 609–967.

APPENDIX 1

NOA (Fig. 4B)

The NOA pattern is described in detail in the discussion. Here we only add that the area is composed by three different main patterns. In its widest version the pattern runs from the limit between Argentina and Bolivia to San Juan supported by four species (see Table 2) the most notably being *Adesmia cytisoides* and *Jarava media*. Several species are distributed as shown in the consensus area in Fig. 4B e.g., *Panicum chloroleucum* and *Polygala argentiniensis*, while the third group of species are lacking in the northernmost part of the area, e.g., *Bulnesia schickendantzii*, *Plectrocarpa rougesii* and *Sporobolus maximus*.

Yavi-Santa Victoria (Fig. 4K)

The Santa Victoria-Yavi area separates as an individual area of endemism in the north-eastern corner of the Jujuy border. The Santa Victoria-Yavi area is supported by 17 endemic species with distributions tightly adjusted to the area, that separates from the general area of endemism at 15% aa, hence the high endemism scores is due to little species overlap between this area and other distribution patterns rather than a high number of endemic species.

Nearly all defining species have been collected in the surroundings of Yavi in semi-arid Puna or along the high Andean road between Yavi and Santa Victoria in sub-humid high Andean, or montane grassland. We suspect that the Santa Victoria-Yavi area is artificially delimited both towards the north and south. Botanical collections are incomplete in southern Bolivia but the eastern slopes of the Eastern Andes range in Salta area almost unexplored botanically except for the road leading to Santa Victoria.

Jujuy (Fig. 4C)

The core of the area that lies within the Eastern

Andes range is supported by 67 endemic species from 48 genera and 23 families (Table 2). The endemic species are found in a wide range of available habitats in semi-desert to humid environments between 500 - >4500 m asl that includes the tropical moist Yungas forest (Sierra Calilegua), mountain grasslands (Sierra de Calilegua, Sierra de Zenta), as well as the slopes of the inner dry valleys (Quebrada de Humahuaca). The few species that are found exclusively above 3500 m, in this area, are from well to sparsely collected high peaks such as Mina Aguilar and Nevado de Chañi, as well as Nevado del Castillo and Cerro de Fundición in Salta.

The Jujuy area is not easily delimited as the core is surrounded by a diffuse border with a gradually decreasing endemism score (Fig. 4C). The high number of sub-sets included in the consensus also indicates that the distribution patterns supporting this area are far from uniform (Table 3). A total of 35 species are endemic to the border (Table 2) that includes same habitats as the core as well as Puna environment between the Eastern and Western Andes range. The main part of the species defining the border area are either species found in the Puna (e.g., *Lobivia einsteinii*, *Mancoa venturii*, and *Senecio punae*) or species present along the the mountain grasslands reaching the Santa Victoria area (e.g., *Macropharynx meyeri*, *Microliabum humile*, and *Silene bersieri*). Part of the area enters Bolivia as four of the defining species have been found in the Tarija department *(Parodia stuemeri, Psychotria argentinensis*, *Puya micrantha*, and *Solanum calileguae*). More of the border species are likely to appear in the southern Bolivia as botanical inventories become more complete.

Salta (Fig. 4L)

Between the high-endemic Jujuy and Tucumán areas lies the Salta area that separates from the main consensus under the 50% consensus criterion. A total of 29 species are endemic to the core area mainly found in montane grasslands, and slopes of the inner dry Valleys.

Like the Jujuy area, the Salta area has diffuse borders that overlap and shares species with the border of the Jujuy area and the northern part of the Tucumán area. The high Andean endemics are restricted to this part of the area where endemic species from Nevado del Castillo and Cerro del Cajón also supports the southern Jujuy or northern Tucumán area respectively. The high mountains peaks of the core area such as Cerro Malcante (5226 m) and Nevados de Palermo (6200m) have not been explored botanically to our knowledge and could add new endemics to this area.

Tucumán (Fig. 4D)

Like the Jujuy area the Tucumán area lies in the eastern Andes range and contains mainly the same habitat types as in the core-Jujuy area. In terms of altitude, temperature, and precipitation, the Tucumán area is just as variable as the core area of Jujuy. A total of 62 species are endemic to the area from a total of 41 genera and 25 families (Table 2).

The area includes tropical moist Yungas forest (eastern slopes of Sierra del Aconquija and Cumbres de Tafi), mountain grasslands (Cumbres del Tafí, Cumbres Calchaquíes and Sierra del Aconquija), as well as the slopes of the inner dry Valleys (Valles Calchaquíes). Species found exclusively above 3500 m asl are mainly from peaks of the two main ranges (Sierra Aconquija and Cumbres Calchaquíes) or from Cerro del Cajón in the northern extreme of Sierra de los Quilmes.

Unlike the Jujuy area, the Tucumán area has well defined limits without diffuse border mainly because species distribution towards the west can be defined as an independent area of endemism, see the Ambato area below.

Jujuy-Tucumán (Fig. 4E)

The combined Jujuy-Tucumán area is defined by species that are found in the cores and/or borders of both the Jujuy and Tucumán areas. The Jujuy-Tucumán area contains the most complex distribution patterns of the study region, being the left over of the main consensus area when all sub-areas are extracted at a consensus criterion of 50%. Like the Jujuy area, the high amount of individual sub-sets that are included in this area indicates that distribution patterns supporting this area are not uniform and variations among these are the main source of the high number of subsets found in the analysis in general.

Ambato (Fig. 4M)

West of the Tucumán area and partly overlapping with this lies the Ambato area (Fig. 4M) that is defined by species that reach further south and/or east than the species defining the Tucumán area.

The high endemic core of the area incudes 16 endemic species (35% aa) found in semi-desert to semi-arid environments from 500-3500 m. These species are mainly found in the montane grasslands along the eastern slopes of Sierra Ambato and in high Andean habitats of Cerro Manchado.

The border of the Ambato area extends from the core towards the north and west partly overlapping with the Belén-Tinogasta area (Fig. 4N).

Belén-Tinogasta (Fig. 4N)

The Belén-Tinogasta area (Fig. 4N) is the western most and least species rich of the three partly overlapping areas of Tucumán, Ambato, and Belén-Tinogasta. The area is supported by 12 species from rare collections in arid or hyper-arid regions of Sierras de Belén or northern Tinogasta. Only a single species [*Tephrocactus geometricus* (A. Cast.) Backeb.] have been collected repeatedly within the area in Sierras de Belén and Sierra de Zapata. The area furthermore includes rare collection of endemic species from the valleys southeast of Cerro Chucula (Tinogasta) and from the eastern slopes of Sierra de Fiambalá northwest of Belén.

Famatina (Fig. 4H)

Endemism in the Famatina area are mainly from the isolated Nevados de Famatina but some species are also found in the surrounding valleys of Chilcito and Vinchina as well as Cuesta de Miranda. The core of the area is supported by 20 endemic species mainly found in semi-desert to semi-arid environments from 1000-4000 m. Twelve of the defining species are endemic to Nevados de Famatina with nine species restricted to altitudes at approx. 4000 m asl including five species of the ultra high Andean *Nototriche* genera. The border of the Famatina areas is composed of a single area mainly defined by four *Gymnocalycium* species from low altitudes in valleys north-east of the Nevados de Famatina.

Andes La Rioja-San Juan (Fig. 4F)

Includes high Andes in La Rioja and San Juan and is mainly defined by species found above 3000 m in the regions of Laguna Brava (La Rioja) and Parque Nacional San Guillermo (San Juan) or collected along the few high Andean roads south of San Guillermo. Few species from the Andean foothill, e.g., *Aphyllocladus ephedroides* and *Solanum glaberrimum* also support the area.

San Juan (Fig. 4G)

The southern San Juan area is found outside the Andes range. The area includes valleys and minor peaks of the Pampeanas Ranges with all defining species found below 3000 m. Highest altitudes of the defining species are found in Sierra Pie de Palo and Sierra del Tontal. The southern San Juan area is one of the driest areas with 50% of the specimens collected in desert environments.

Inner valleys and Pampeanas Range

The four partly overlapping areas below are defined by species mainly found in the inner valleys, slopes and summits of the Sierras Pampeanas. Three of the four areas include species that reach above 4000 m asl with the lower part of the area set by the altitude of the valley button in the respective areas. Species from the areas are restricted to semi-desert and semi-arid habitats while few enter desert environments. Sub-humid locations are only reached in these areas at high altitudes with low annual mean temperature rather than higher rainfall.

Salta-Catamarca summits and dry inner valleys (Fig. 4O). The northernmost of the Pampeanas Range areas are defined by species distributed along valleys and high Andean locations from Santa Rosa de Tastil (Quebrada del Toro, Salta) to Sierra Ambato and Quebrada de Belén (Catamarca).

Catamarca-La Rioja summits and dry inner valleys (Fig. 4P). This area includes mainly the locations Hualfin, Andalgalá, Londres, Cuesta de Zapata, and Mina Capillitas in Catamarca as well as Los Corrales in Famatina, La Rioja.

Several species are found in the semi-desert of the inner valleys, e.g., the five Cactaceae species that defines the area as well as *Sclerophylax cynocrambe* from the arid radiation of Solanaceae. The high Andean part of the area is defined by species distributed along the summits of the Calchaquíes, Ambato and Famatina e.g., *Poa plicata* and *Viola triflabellata*.

La Rioja-San Juan summits and dry inner valleys (Fig. 4Q – obtained under cell size 0.5°x1.0°). The area is mainly defined by species distributed in valleys from southern Catamarca to San Juan. Several of the endemic species from a wide array of families reach desert environments in this area, e.g., *Flourensia hirta* and *Senecio sanagastae* (Asteraceae), *Lobivia famatimensis* and *Tephrocactus alexanderi* (Cactaceae), *Senna fabrisii* (Fabaceae), *Guindilia cristata* (Sapindaceae), and *Sclerophylax kurtzii* (Solanaceae). Only few species in this area reach high Andean environments, e.g., *Zephyranthes diluta* (Amaryllidaceae) and *Adesmia nanolignea* (Fabaceae) that are found along the high Andes of La Rioja and San Juan.

Valle Fértil (Fig. 4R – obtained under cell size 0.5°x1.0°). This minor area of endemism only appears when using longitudinal cells of 0.5ºx1.0º in which case four species from different families define the area (Table 2). The main part of the area consists of the valley between Sierra de Valle Fértil/Sierra de La Huerta in San Juan and Sierra de Los Llanos/Sierra de las Minas in La Rioja. This area also reaches the northern part of San Luis, where nearly all defining species have been confirmed.