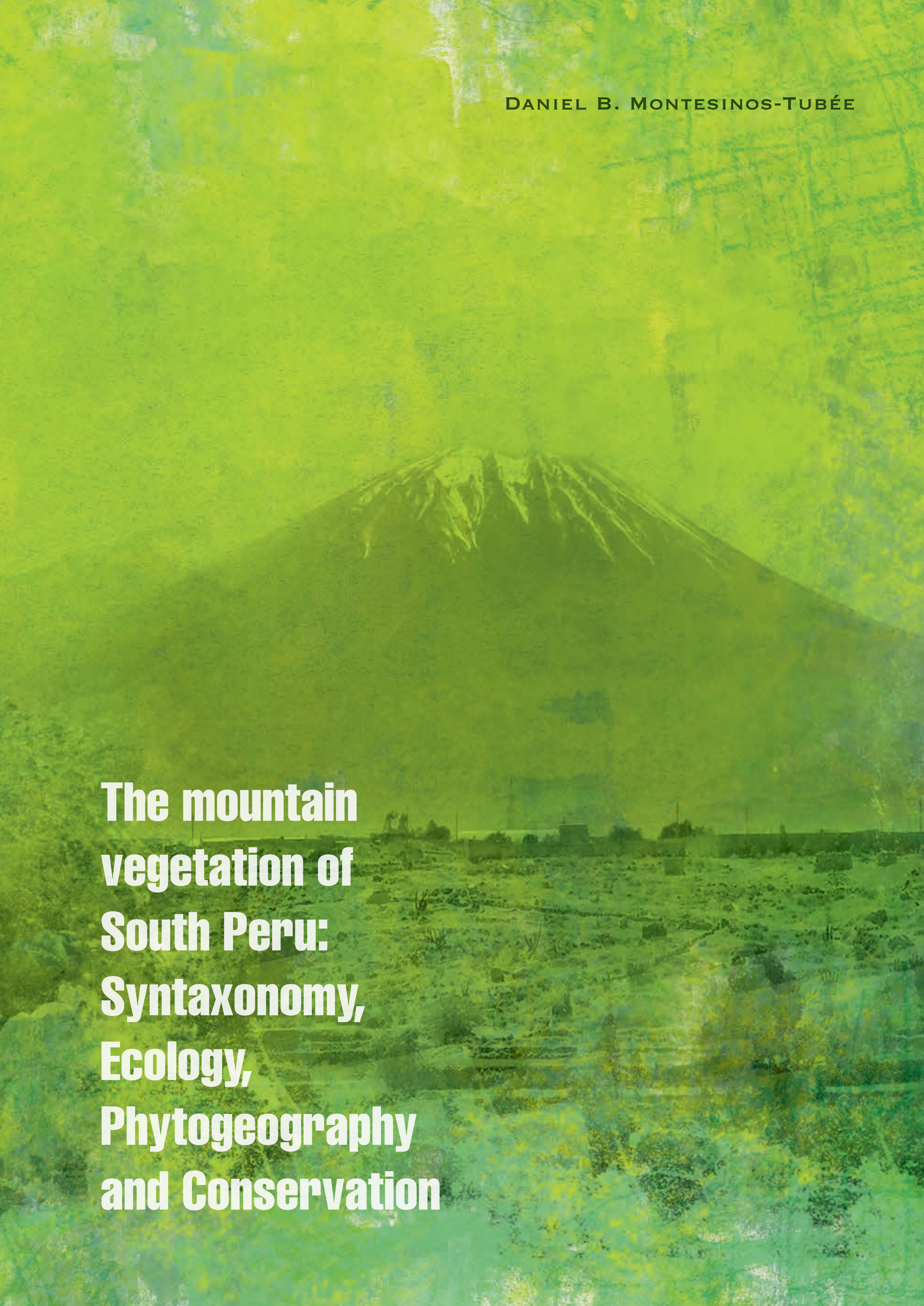
Daniel B. Montesinos-Tubée



The mountain vegetation of South Peru: Syntaxonomy, Ecology, Phytogeography and Conservation

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Daniel B. Montesinos-Tubée

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This research was conducted under the auspices of the C.T. de Wit Graduate School of Production Ecology and Resource Conservation (PE&RC)

The mountain vegetation of South Peru: Syntaxonomy, Ecology, Phytogeography and Conservation

Daniel B. Montesinos-Tubée

Thesis
submitted in fulfillment of the requirements for the degree of doctor at
Wageningen University
by the authority of the Rector Magnificus
Prof. Dr. A.P.J. Mol,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Friday 15 April 2016
at 1:30 p.m. in the Aula.

Daniel B. Montesinos-Tubée
The mountain vegetation of South Peru:
Syntaxonomy, Ecology, Phytogeography and Conservation,
334 pages.

PhD thesis, Wageningen University, Wageningen, NL (2016)
With references, with summaries in English, Dutch and Spanish.

Printed & Lay Out by: Proefschriftmaken.nl || Uitgeverij BOXPress

ISBN 978-94-6257-679-7

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CHAPTER 1

Introduction

The Peruvian Andes

The Peruvian Andes belongs to the central bioregion of the Andes. It is one of the biodiversity hotspots of the world. The altitude, topography and geology in the Andes are very diverse, which results in a complex biogeography. A large diversity of plant communities can be found in the southern Peruvian Andes, in dry valleys, highland mountain valleys, grassland plateaus, highland cushion bogs, lakes and on subnival summits.

During the past decades the overwhelming taxonomic and ecological diversity of the Andes, as well as the ecological importance of these mountain ecosystems has been recognized (Arroyo et al. 1982; Cano et al. 2010; Cleef 1979; Cooper et al. 2010; Flores et al. 2005; Galiano 1990; Gutte 1985, 1986; Lozano et al. 2009; Pinto & Kirberg 2009; Luebert & Gajardo 2005; Montesinos-Tubée 2011a, 2012a,b, 2013b, 2014b, 2015b; Montesinos-Tubée & Kool 2015; Montesinos et al. 2012; Montesinos-Tubée et al. 2015a,b, Chapter 5; Navarro & Maldonado 2005; Orellana 2014; Orrego et al. 2013; Pestalozzi & Torrez 1998; Ruthsatz 1977; Seibert & Menhofer 1991, 1992, 1993; Smith 1988; Teillier 1998, 1999; Tovar 2009; Villagrán et al. 1983; Yurapaitán & Albán 2003). However, the number of studies on biodiversity of Peruvian mountain ecosystems, particularly of the Moqueguan Andes is still very small (Arakaki & Cano 2003; Schwarzer et al. 2010; Montesinos-Tubée 2011a).

Most of the studies on the vegetation of the Peruvian Andes have been carried out in the central and southern regions (Galán de Mera et al. 2002b, 2003, 2004, 2009, 2011b, 2012a, 2014; Gutte 1980, 1986, 1987, 1988; Gutte & Müller 1985; Montesinos et al. (2012), Montesinos-Tubée et al. (2015a), Navarro (1993), Navarro & Maldonado (2005), Rivas-Martínez & Tovar (1982), Ruthsatz (1977), Seibert & Menhofer (1991, 1992, 1993) with some exceptions from North Peru (Tovar 2009; Sabogal 2014).

The lack of sufficient information on the floristic composition of the Andean ecosystems of Peru is holding back a good estimation of the floristic diversity, the botanical composition of most mountainous ecosystems, and the status of conservation of the endemic flora in such areas.

In the Moquegua and Arequipa regions partly the lomas formations and scrubland-grassland ecosystems have been studied, but almost no knowledge is available for xeric dry ecosystems. The descriptions of the different lomas formations in Moquegua by Arakaki & Cano (2001, 2003) and Dillon (2005) provide a first overview. According to (Vargas 1940; Péfaur 1982; Brack Egg & Mendiola 2004; Galán de Mera et al. 2011a), the definition of lomas is referred to the southern Peruvian desert in boundary with the Pacific Ocean which is characterized by two types of vegetated areas. One type comprises the set of river valleys cutting through the desert which are covered with a riparian type of vegetation. In these valleys regional agriculture has developed. The other type is a patchy vegetation belt on the seaward slope of the Coastal Range running parallel to the coast, and called the Lomas. These are presented as islands of vegetation separated by variable distances of completely arid habitats (Ferreyra 1993; Rundel et al. 1991; Trinidad et al. 2012). The more luxurious vegetation in the lomas areas may be related to the greater water availability due to the fog during El Niño (Eichler & Londoño 2013).

Previous phytosociological studies that describe associations and higher syntaxonomical units are only known for the xeric-scrublands (Galán de Mera et al. 2003, 2009, 2011b) and for the scrublands, grasslands and cushion communities of North Moquegua (Montesinos et al. 2012; Montesinos-Tubée et al. 2015b; Chapter 5).

Altitudinal zonation

It has been widely recognized that altitudinal gradients in mountain ecosystems have considerable impact on the distribution of diversity (Cuello 2010). The mountainous flora is primarily determined by the great variation in temperature (a function of altitude) as has been established in previous studies (Cleef 1979; Vuilleumier & Monasterio 1986; López 2003; Sklenář & Balslev 2005). We classified the mountainous vegetation series in xeric-scrubland (2000–3260 m), prepuna (3200–3800 m), puna (3800–4500 m) and superpuna (4450–4800 m). This classification follows Rivas-Martínez & Tovar (1983), Huber & Riina (1997), Kuentz et al. (2007) and Montesinos et al. (2012).

Puna is the name given to extensively used highlands in the central and southern Andes of South America and particularly to their distinctive alpine grassland vegetation (Cabrera 1968; Navarro 1993; Galán de Mera et al. 2003, 2009, 2011b, 2014; García & Beck 2006;

Montesinos et al. 2012).

In this study we define the superpuna as the zone between 4450 meters and 4800 m (snowline). It is characterized by average annual temperatures ranging from 6°C at 4500 m to 0°C at 4800 m. Mean annual precipitation is low and varies between 400 and 600 mm per year (Servicio Nacional de Meteorología e Hidrología del Perú 2013). In the north of Moquegua (South Peru), the superpuna vegetation is characterized by dwarf and erect shrubs, tussock grasses, annual herbs, ground rosettes, cushions, mats and annual grasses. The majority of the Peruvian puna grasslands are grazed by livestock (predominantly llamas and alpacas) (Wilcox et al. 1986).

Land use and nature conservation

As in other South American countries, the Peruvian Andes are suffering from increased human intervention and many forests and scrublands have been converted into agricultural land. Also mining activities, urbanization and increased fire frequencies generate a loss of diversity in key areas of endemism in the Peruvian Andes. These developments change water flows and erosive processes, affecting dramatically soil stability, and the supply of water.

Fortunately, a relatively large part of the mountainous ecosystems of North Moquegua are preserved but not by national reserves. Instead, local communities preserve the grasslands in designed pastoral areas and organize educational programs for the conservation of local ecosystems. One of the main objectives of this research is to provide a sufficient scientific basis for the foundation of a national park in the north of the Moquegua department. Gutiérrez Tito (2012, 2013) emphasizes on the basis of a detailed analysis, the urgent need of the conservation of areas with high species diversity like North Moquegua and other geographic regions of the department. Moreover, Chancayauri (2008) presents guidelines for conservation of the *Polylepis rugulosa* forests in Central Moquegua. In addition, the xeric ecosystems surrounding the Arequipa Province are prone to a great loss of diversity due to the incessant urbanization projects without any environmental protection (Montesinos-Tubée et al. 2015a).

Approach of the study

The study of vegetation along the altitudinal gradient in North Moquegua and the Arequipa Province was done using a floristic and phytosociological approach. We surveyed the diversity of flora and vegetation in these regions along altitudinal gradients. We addressed issues of phytosociology, floristic diversity and phytogeography. The observed patterns were interpreted on the basis of comparisons with other regional and interregional studies.

Research aim

The aim of this study was to explore the structure, floristic composition and diversity of xeric, scrubland, grassland and cushion communities, and to relate these vegetation characteristics to different environmental gradients, including altitude.
The phytogeographical patterns of the xeric and puna flora were compared to other such ecosystems in Peru, Ecuador, Colombia, Bolivia, Chile and Argentina. The results of this study provide the necessary basis for conservation and biodiversity management in the region.
In addition to the vegetation studies in this thesis, six new species to science were described and presented in chapter 7.

Thesis outline

Chapter 2 describes the different plant communities and the range of altitude at which there communities occur which are present in the xeric and scrublands in the Arequipa Province in South Peru. Vegetation in arid areas is primarily limited by precipitation. The xerophytic vegetation was studied after extreme rainfall had promoted exceptionally lush vegetation and a high aboveground floristic diversity. This chapter gives a description of the floristic diversity and structure of these plant communities, and presents a syntaxonomic scheme to classify the xeric communities and scrublands of this part of the Peruvian Andes. It is based on a quantitative analysis of physiognomy, floristic composition, ecological relations and the distribution of the different plant communities. Finally conservation issues are addressed and discussed.

Chapter 3 comprises the classification of prepuna scrubland vegetation communities found in the mountainous areas of North Moquegua at altitudes between 3470 and 3700 m. Here we present a schematic representation of the vegetation zonation across the altitudinal gradient. Land use and conservation issues are addressed in relation to their impacts on scrubland ecosystems.

In **Chapter 4** we studied the plant communities present in the puna of the mountains of North Moquegua comprising *Puya raimondii* patches, grasslands and chasmophytes. A syntaxonomical description is presented as well as an analysis of the structural similarities, floristic composition and their distribution along an altitudinal gradient between 3750 and 4500 m. We also addressed the possible effects of human disturbance.

Chapter 5 covers the classification of the superpuna plant communities found in the upper mountains and summits of North Moquegua. A syntaxonomical classification is presented for cushion communities, grasslands and vegetation growing on scree slopes. As well as in the previous chapters, the most important conservation issues are discussed.

Chapter 6 gives an analysis of the phytogeographical patterns in the flora of the mountain slopes of the prepuna, puna and superpuna in North Moquegua. It provides an analysis of the floristic connections with neighbouring Andean ecosystems in Colombia, Ecuador, Peru, Bolivia, Chile and Argentina. Using ordination and dendrogram analyses, we explored the relation between the phytogeographical patterns of the puna flora of north Moquegua and altitude and humidity and also their similarity to the other puna ecosystems in South America.

Chapter 7 presents six species new to science: *Paronychia ubinensis* Montesinos (Caryophyllaceae), *Senecio moqueguensis* Montesinos, *S. sykorae* Montesinos, *S. tassaensis* Montesinos (Asteraceae), *Arenaria acaulis* Montesinos (Caryophyllaceae) and *Tigridia arequipensis* Montesinos, Pauca & I. Revilla (Iridaceae).

Chapter 8. In this chapter a general discussion is given of the results and conclusions based on all chapters. Here we discuss our results in a broader context.

CHAPTER 2

Species composition and phytosociology of xerophytic plant communities after extreme rainfall in South Peru

Montesinos-Tubée, D.B., Sýkora, K.V., Quipuscoa-Silvestre, V. & Cleef, A.M.

Phytocoenologia 45(3): 203–250, 2015

Abstract

We present a phytosociological overview of the arid and semi-arid montane vegetation of the province of Arequipa in southern Peru. The xerophytic vegetation was studied after extreme rainfall had promoted exceptionally lush vegetation and a high aboveground floristic diversity. We used TWINSPAN for classification and Detrended Correspondence Analysis for gradient analysis of our relevés. PC-ORD was used to show the hierarchical similarity structure of the syntaxa, and to compare them with related communities in Peru and surrounding countries from literature. We present a synoptic table, and describe the physiognomy, floristic composition, ecology and spatial distribution of the plant communities. In total, we recorded 187 plant species, including 50 endemics, in 196 phytosociological relevés distributed over 2030 km² at an elevation between 2020 and 3260 m. The relevés were assigned to three alliances in the class *Opuntietea sphaericae*. The vegetation consists mainly of native species of trees, shrubs, grasses, succulents, annual herbs, and ferns. The most diverse families were *Asteraceae*, *Cactaceae*, *Solanaceae*, *Malvaceae*, *Boraginaceae*, *Fabaceae*, *Poaceae*, *Amaranthaceae* and *Pteridaceae*. Within the class *Opuntietea sphaericae*, three alliances have been distinguished of which two are new. The *Ambrosio artemisioidis-Weberbauerocerion weberbaueri* comprising six associations was recorded on barren hillsides between 2000 and 2900 m in the Arequipa city boundary zones. The *Corryocaction brevistyli* defines xerophytic scrub between 2700 and 3200 m in semi-dry regions bordering the puna grasslands. It contains the *Balbisio weberbaueri-Ambrosietum artemisioidis* and the *Aloysio spathulatae-Corryocactetum brevistyli*, all in need of further investigation as they lack diagnostic species. A unit clearly distinguished by *Weberbauerocereus rauhii* and *Neoraimondia arequipensis* is here described as a new alliance, *Neoraimondio arequipensis-Weberbauerocerion rauhii*. It grows in inter-Andean valleys in dry regions (1100–2200 m), with abundant cacti accompanied by few xerophytes.

Keywords: Andes; Arequipa province; *Cactaceae*; climate event; *Opuntietea sphaericae*; Peru; syntaxonomy

Introduction

In the arid regions of southern Peru, rainfall is very variable. Dry years with very limited seasonal rainfall alternate with periods of abundant rainfall that result in germination and sprouting of numerous annual herbs and geophytes which are not observed during normal periods of precipitation. Interannual variability in summer precipitation is partly influenced by the El Niño Southern Oscillation (ENSO) and the strength and position of the Bolivian High and Southern Hemisphere Subtropical Convergence Zones or SACZ (Lenters & Cook 1999). In 2012, rainfall was exceptionally high; a climatic event that apparently takes place every 10 to 15 years in the drier regions of South Peru (Huertas 2009). The rainfall tripled the normal precipitation values in Arequipa province (Fig. 1) and resulted in the emergence of species that do not appear in drier years.

Thibault & Brown (2008) studied how extreme precipitation events greatly modify the structure and composition of arid and semi-arid ecosystems, noting that extreme weather events will increase in frequency and magnitude due to climate change and ENSO events (Dillon & Rundel 1989), and pointing out that the ecological impacts of such events are still poorly understood. Studies by Galán de Mera & Vicente Orellana (1996), Galán de Mera & Gómez Carrión (2001) and Galán de Mera et al. (2009, 2010) provide important sources to understand the composition of plant communities in South Peru during normal periods of (little) precipitation. As they sampled the vegetation in dry periods, a lot of species emerging after exceptional rainfall were missed. The vegetation composition of the arid ecosystems of the province and department of Arequipa in southern Peru, especially after abundant rainfall, is still insufficiently studied. The floristic relationships between the mesotropical and supratropical bioclimatic zones are still poorly understood and documented.

Sarmiento (1975) presented a general overview of the phytogeography and vegetation ecology of arid plant formations in South America. Since then, overviews of the vegetation in the arid and subarid regions have been given from North Chile by Villagrán et al. (1981, 1982), Gutiérrez et al. (1998), Luebert & Gajardo (2000, 2005), Navarro & Rivas-Martínez (2005) and Luebert & Pliscoff (2006), from Ecuador (Loayza & Morrone 2011), Bolivia (Navarro 1996; Navarro & Maldonado 2002) and Argentina (Kiesling 1999). The floristic composition and ecology of various ecosystems (coastal and mountainous) in the south of Peru have also been studied (Asociación Especializada para el Desarrollo Sostenible 1998; Arakaki & Cano 2003; Franco et al. 2004; Galán de Mera et al. 1997, 2002a, 2002b, 2003, 2009, 2010, 2011a, 2011b; Gutte 1985, 1986; Kuentz et al. 2007; Schwarzer et al. 2010; Talavera et al. 2010; Montesinos-Tubée 2010a, 2011a, 2012a, 2012b; Montesinos et al. 2012). In Arequipa province, the floristic composition of the arid ecosystems has been studied by Weberbauer (1912, 1945), Linares Perea & Benavides (1995), Puig et al. (2002), Linares Perea (2005), Linares Perea et al. (2010) and Heim (2014). Galán de Mera et al. (2010) recently presented a bioclimatic classification of the department of Arequipa, mentioning the indicator species for the different mountain slopes and their floristic relations.

The arid regions of South Peru contain many endemic cactus species, distributed along the western slopes of the central Andes (Weberbauer 1945; Rauh 1958; Britton & Rose 1919, 1920; Ritter 1981; Aragón 1982; Hunt 1992, 2006; Lombardi 1995; Galán de Mera & Vicente Orellana 1996; Sahley 1996; Mariño et al. 1998; Galán de Mera & Gómez Carrión 2001; Mauseth et al. 2002; Arakaki 2003; Arakaki et al. 2006; Galán de Mera et al. 2009, 2011b; Montesinos-Tubée 2010a, 2011a, 2012a; Ostolaza 2011, 2014). Notwithstanding their diversity, abundance and competitiveness, hardly anything is known about their ecology, especially under extreme climatic conditions. Moreover, little is known about the endemism of plant species in the cacti communities of the specific arid ecosystems. Vegetation research is urgently needed, as the habitats occurring along the western slopes of the Andes are underrepresented in Peru's national reserve system (Sahley 1996) and have been ranked to be of high priority for research and conservation (Centro de Datos para la Conservación 1986).

Our study had three objectives: (a) to study the species composition, cover and structure of the xeric vegetation and xeric scrub vegetation in the Arequipa province, South Peru under the influence of an extreme climatic event; (b) to analyze the floristic composition, vegetation structure, ecology and distribution of the vegetation along an altitudinal gradient from 2020 to 3260 m, and (c) to present a syntaxonomic overview of the succulent rich vegetation of South Peru based on relevés made in a period of vegetation development following abundant rainfall.

Study area

The 25 sampled transects (Fig. 2) are located in seven districts in the Arequipa province (Arequipa department, South Peru) between 2020 m and 3260 m of elevation. The study area in the province of Arequipa is located between 16°44'10" S; 71°18'04" W and 16°10'51" S; 71°43'14" W. The geology comprises Cretaceous and Tertiary igneous intrusive rocks and marine sediments, Tertiary and Quaternary volcanic rocks (primarily ignimbrites), and Quaternary eolian and alluvial sediments (Holmgren et al. 2001). In the Yura region there are Callovian fossils with sandstone sediments and volcanic rocks originating from the Jurassic era (Westermann et al. 1980). In general terms the relief is volcanic, with some sedimentary quartzite and sandstones (Treacy 1994; Galán de Mera et al. 2009). The main rivers are the Chili and Sabandia, which flow through Arequipa city. Their wide valleys are intensively used for agriculture. The plains and slopes west, north and east of Arequipa city are formed of the deposits of three volcanoes: Misti (5822 m), Chachani (6022 m), and Pichu-Pichu (5415 m). The southern rocky and more arid slopes are granite outcrops overlain by sandy soil. Table 1 presents the geographic areas in the administrative districts studied, altitudinal range (m) and average elevation, the total number of relevés per district, slope inclination and aspect, and biogeographic zone.

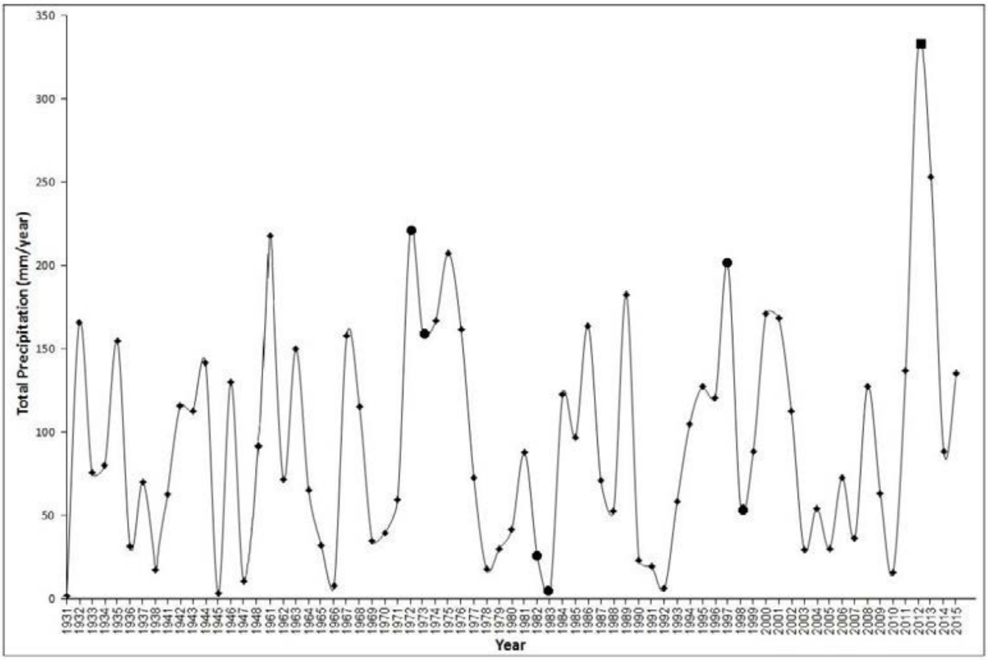

Figure 1. Precipitation data for the years 1931–2015 (data missing for 1939 and 1940, 1949 and 1960) averaged by combining data from the meteorological stations of Socabaya (2337 m a.s.l.), La Pampilla (2371 m a.s.l.), Huasacache (2207 m a.s.l.) and Characato (2641 m a.s.l.), all in Arequipa city (16°26'10'' S; 71°30'47'' W). The latest El Niño events occurred in the years 1972–1973, 1982–1983 (missing data for 6 months) and 1997–1998. Data obtained from ONERN (1974), Sahley (1996) and Servicio Nacional de Meteorología e Hidrología del Perú (2013). The diamonds indicate normal years, circles indicate El Niño events and the square shows the peak precipitation (333.6 mm) reached in 2012.

Bioclimate

We used the methodology of Rivas-Martínez et al. (1999) and following approaches by Galán de Mera et al. (2010, 2012a), to determine the thermicity index (*It*) which is used as a measure of the climatic thermic restrictions and is applied by the following formula:
$It = (T + M + m)\ 10$
T: mean annual temperature (°C), M: mean highest temperature of the coldest month (°C), m: mean lowest temperature of the coldest month (°C).
We also applied the approach by Kuentz et al. (2007) and Galán de Mera et al. (2012a). The following bioclimatic belts were identified according to our research: thermotropical (Uchumayo district and lower slopes of Yura district): *It* = 610–471, 2000–2600 m; mesotropical (Arequipa and Chiguata zone): *It* = 470–311, 2100–3260 m.
Precipitation records were registered for 2012 in the La Pampilla station (2371 m) with 319.8 mm, Huasacache station (2207) with 266.9 mm and Socabaya station (2337 m) with 333.6 mm. The relation between precipitation and elevation largely depends on

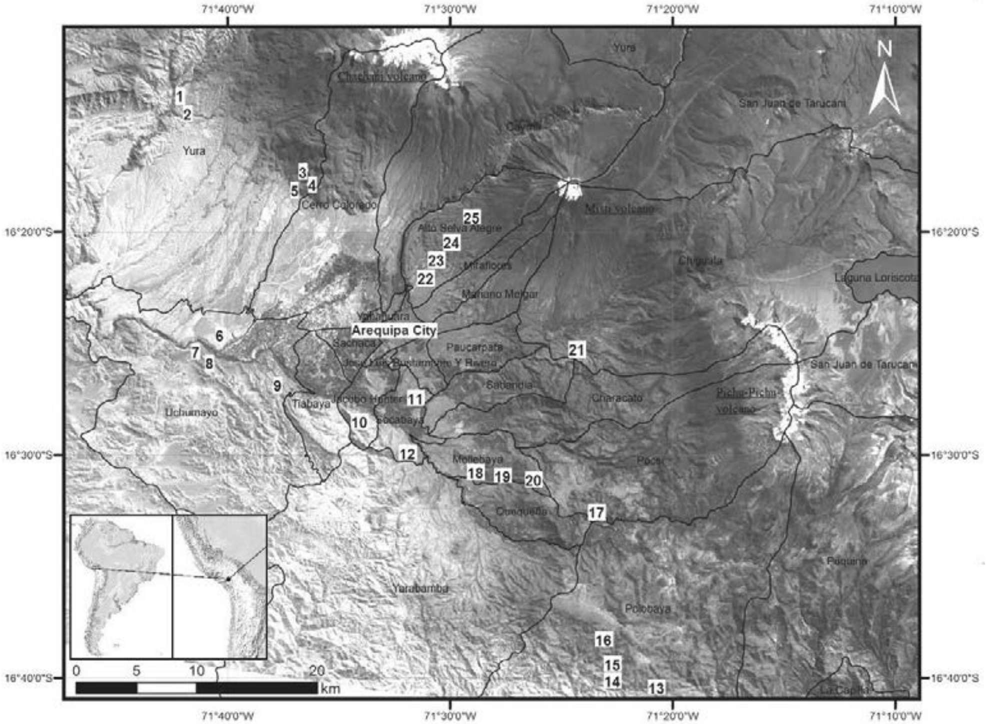

Figure 2. Map of the fieldwork area in Arequipa province. The administrative districts are indicated. The numbers show the locations of the studied sites. Image source: Landsat 7 Enhanced Thematic. Mapper (ETM+) Acquisition date = 10 May, 2001. Glovis Visualization Portal (http://www.glovis.usgs.gov), a part of the Earth Resources and Science Center (EROS) of the USGS.

distance from the Andean crest, due to the lack of rising air masses on the Pacific slope of the Andes and because the orographic precipitation that do cross the Andes rain out at high elevations, which is why, in the lee of the mountain range, the precipitation decreases rapidly as elevation decreases (Holmgren et al. 2001, Roe 2005).
According to Holmgren et al. (2001) and Galán de Mera et al. (2010, 2012a), the upper limit of the thermotropical bioclimatic zone in the Arequipa province is at an elevation of between 2000 and 2100 m. The mesotropical bioclimate extends between 2100 to 3100 m, and is succeeded by the mesotropical-supratropical bioclimate, which extends from 3100 to 3800 m.

Methods

Phytosociology and classification

The relevés were set out following the Zürich-Montpellier method (Braun-Blanquet 1979) in plots without essential environmental differences in the vegetation. Structural differences were typical and can consequently be considered as a characteristic system

Table 1. Localities studied in Arequipa province; bioclimatic zonation according to Rivas-Martínez et al. (1999), Kuentz et al. (2007) and Galán de Mera et al. (2012).

	District	Areas	# relevés	Lat S	Lon W	Altitude (m)	Slope (°)	Aspect	Bioclimatic zone
1	**Alto Selva Alegre**	Cerro Pacheco, Quebrada Peral	**38**	16° 19'	71° 28'	2700–3190	5–40(18.7)	S(SW)-E(SE)	mesotropical
2	**Chiguata**	Quebrada Cañuma	**5**	16° 24'	71° 34'	3020	20–45(33.6)	S, W	mesotropical
3	**Jacobo Hunter**	Cerro San Ignacio, Huasacache	**15**	16° 28'	71° 34'	2220–2600	15–50(25.7)	W	mesotropical
4	**Mollebaya**	Molinoyoc, Cerro Pajonal	**6**	16° 29'	71° 28'	2800–3020	4–45(23)	N, S	mesotropical
5	**Pocsi**	Pampa Culanayoc	**6**	16° 31'	71° 24'	2990–3030	8–10(9)	N, S	mesotropical
6	**Polobaya**	Quebrada de Chapi, Quebrada Escalerilla	**29**	16° 42'	71° 19'	2340–3260	6–45(19)	all	mesotropical
7	**Socabaya**	Cerro Llorón, Lara	**39**	16° 27'	71° 31'	2300–2580	2–14(8)	W-E	mesotropical
8	**Uchumayo**	El Huayco, Congata, Variante Uchumayo	**24**	16° 25'	71° 41'	2020–2450	8–50 (31.4)	E, S	thermotropical
9	**Yura**	Corontorio, Cerro Los Andes	**34**	16° 13' - 16° 18'	71° 36' - 71° 41'	2590–3260	5–60(26.2)	all	thermotropical, mesotropical

property (Glavac 1996). Much attention was paid to the uniformity of the environmental factors and the distribution of species within the plot. According to Glavac (1996), the general concept is that the splitting of the plant communities into mosaic microcoenoses finally hinders the possibility to distinguish general vegetation types. Due to the mosaic structure of the vegetation at the studied scale of 10–100 m², a certain degree of structural heterogeneity is inherent to the stands. Depending on the scale a certain inhomogeneity is always enclosed and has to be accepted (Dierschke 1994). According to Barkman (1979) even so-called homogeneous stands or phytocoenoses are actually mosaics consisting of finer mosaics, etc. This compound mosaic structure of vegetation seems to be of a general nature.

Fieldwork was conducted during March and April 2012 (the peak flowering period of the vast majority of annual species after the precipitation period between December and April). Relevés were made in xeric vegetation after exceptional rain. Many species remaining dormant in the much more common dry years emerged and contributed to unusually high species diversity. In total, 196 relevés were made in 25 transects (in nine districts), within the altitudinal range of 2020–3260 m. The relevés were 25 m² in communities with abundancy of annual herbs and shrubs, and columnar cacti and 64 m² in scrubland communities.

For each relevé, the presence of species was noted and the percentage actual cover per species was estimated (Mueller-Dombois & Ellenberg 1974; Knapp 1984). For calculations, the percentage values were transformed into a nine-point ordinal cover/abundance scale (Westhoff & Van der Maarel 1973): 1% = 1; 2% = 2; 3% = 3; 4–7% =

4; 8–20% = 5; 21–37% = 6; 38–68% = 7; 69–88% = 8 and 89–100% = 9. Presence class values are presented in percentage (1–100%) for Table 3 and Appendices 1–8.

The relevés were classified with TWINSPAN (Hill 1979) and a synoptic vegetation table was constructed. As syntaxa described in literature were based on relevés mostly or exclusively made in normal years with low rainfall, we only used perennial species for the comparison with previously published syntaxa. However as our relevés were all made in the same climatic conditions, all species were used while comparing the syntaxa based on our dataset.

Besides an ordination diagram based on Detrended Correspondence Analysis (DCA: CANOCO 4.5, Ter Braak & Šmilauer, 2002) as well as a Farthest Neighbour Clustering PC-ORD, Sørensen, Bray-Curtis Distance Measure) (McCune & Mefford 1999) were used to show the similarity in the hierarchical structure of the syntaxa described and to enable the syntaxa to be compared with related communities from literature.

In the TWINSPAN analysis on our own data we used all relevés and species. As all relevés were made in the same wet season, all species including the annuals were used to compare the plant communities. In the DCA and cluster analysis we used a dataset (with presence class values I-V) containing our communities and the communities already published, in which the annuals were excluded and only perennials, except those with very low occurrence, were used. Annuals were excluded because they could not be used for comparison, as the vegetation surveys of other authors were done in dry periods when the specific annuals were not present. For community comparison by DCA and cluster analysis, 55 perennial and biannual species (including those listed by Galán de Mera & Vicente Orellana 1996; Galán de Mera & Gómez Carrión 2001; Galán de Mera et al. 2003, 2009, 2011b) were included which occurred with high presence even outside the rainy season over the studied communities, such as *Adesmia augusti, Aloysia spathulata, Ambrosia artemisioides, Aphyllocladus denticulatus, Armatocereus riomajensis, Atriplex atacamensis, Atriplex rotundifolia, Austrocylindropuntia subulata, Balbisia meyeniana, Balbisia weberbaueri, Browningia candelaris, Browningia viridis, Cantua candelilla, Cantua volcanica, Carica augusti, Corryocactus aureus, Corryocactus brevistylus, Corryocactus puquiensis, Croton ruizianus, Diplostephium meyenii, Encelia canescens, Ephedra americana, Euphorbia apurimacensis, Euphorbia tacnaensis, Gochnatia arequipensis, Grindelia boliviana, Grindelia tarapacana, Haageocereus limensis, Haageocereus platinospinus, Haageocereus pluriflorus, Jatropha macrantha, Kageneckia lanceolata, Krameria lappacea, Lantana scabiosiflora, Larrea divaricata, Lycianthes lycioides Lycium distichum, Junellia arequipense*[1]*, Neoraimondia arequipensis, Opuntia sphaerica, Opuntia tunicata, Oreocereus hempelianus, Oreocereus tacnaensis, Paronychia microphylla* var. *arequepensis, Prosopis laevigata* var. *andicola, Proustia berberidifolia, Senecio yurensis, Senna birostris* var. *arequipensis, Stipa ichu, Tecoma fulva* subsp. *arequipensis, Tecoma*

1 Treated as *Junellia arequipense* (Tropicos 2014).

tanaeciiflora, Trixis cacalioides, Weberbauerocereus rauhii, Weberbauerocereus torataensis and Weberbauerocereus weberbaueri.

As the dendrogram with all communities showed a very dissimilar group of communities, this outgroup was excluded in a second run, as well as in the DCA.

New syntaxa were described with due regard to the International Code of Phytosociological Nomenclature (Weber et al. 2000).

Floristics

The collected plant specimens were identified at the Universidad Nacional de San Agustín (HUSA) and the Universidad Nacional Mayor de San Marcos (USM) herbariums, using the digital versions of Missouri Botanical Gardens (MO) and Field Museum of National History (F). Botanical collections were later labeled and placed at the USM, HUSA, Michael Owen Dillon Institute (HSP), the Universidad Nacional San Antonio Abad del Cusco herbarium (CUZ), the Universidad Nacional de Trujillo (HUT), the Universidad Nacional de Cajamarca (CPUN) and the Missouri Botanical Gardens (MO). Information on the distribution of species was obtained from Asociación Especializada para el Desarrollo Sostenible (1998), Arakaki & Cano (2003), Franco et al. (2004), Galán de Mera et al. (2003, 2009, 2012a), Schwarzer et al. (2010), Talavera et al. (2010), Montesinos-Tubée (2011a, 2012a), Montesinos et al. (2012), Galiano et al. (2013) and Heim (2014). In the synoptic table we added the status of species with an asterisk (Brako & Zarucchi 1993; León et al. 2006; http://www.tropicos.org): endemic (in Peru), native (America) and introduced.

Results and discussion

Syntaxonomic overview

Based on a total of 196 relevés made on the xerophytic slopes of the Arequipa province between 2000 and 3260 m the vegetation sampled is assignable to one class (*Opuntietea sphaericae*) and one order (*Oreocereo leucotrichi-Neoraimondietalia arequipensis*). Syntaxa from literature used here for comparison are given in small script. The following syntaxa were distinguished:

Opuntietea sphaericae Galán de Mera & Vicente Orellana 1996

Oreocereo leucotrichi-Neoraimondietalia arequipensis Galán de Mera & Vicente Orellana 1996

The *Opuntietea sphaericae* has been defined on the presence of *Opuntia sphaerica*, a cactus which is distributed from Peru to Argentina (Britton & Rose 1919, 1920; Hunt 1992) and is well represented in a variety of vegetation studies in Peru (Galán de Mera & Vicente Orellana 1996; Galán de Mera et al. 2001, 2002a, 2003, 2005, 2009, 2011b, 2012a) and Chile (Luebert & Gajardo 2005).

The affinity of the studied vegetation to the order *Oreocereo leucotrichi-Neoraimondietalia arequipensis* is defined by the presence of *Ambrosia artemisioides, Armatocereus* *riomajensis, Corryocactus aureus, Haageocereus platinospinus, Neoraimondia arequipensis* and *Oreocereus hempelianus*.

Ambrosio artemisioidis-Weberbauerocerion weberbaueri all. nov. (*Holotypus*: *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* Montesinos-Tubée, Cleef, Quipuscoa-Silvestre & Cleef 2015

1. *Weberbauerocereo weberbaueri-Browningietum candelaris* Galán de Mera & Vicente Orellana 1996 (*Typus*: Table 2, col. 15 in Galán de Mera et al. 2011b)

1.1 *haageocereetosum pluriflori* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 6, Table 2, col. 1.1)

1.2 *onoseridetosum odoratae* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 21, Table 2, col. 1.2)

1.3 *neoraimondietosum arequipensis* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 30, Table 2, col. 1.3)

2. *Senecioni yurensis-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 17, Table 2, col. 2.2)

2.1 *oenotheretosum verrucosae* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 6, Table 2, col. 2.1)

2.2 *chionopappetosum benthamii* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 17, Table 2, col. 2.2)

2.3 *ephedretosum americanae* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 32, Table 2, col. 2.3)

2.4 *eremodrabetosum schulzii* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 39, Table 2, col. 2.4)

3. *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 13, Table 2, col. 3.1)

3.1 *kramerietosum lappaceae* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 13, Table 2, col. 3.1)

3.2 *jatrophetosum macranthae* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 28; Table 2, col. 3.2)

4. *Lycio distichi-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 4, Table 2, col. 4)

5. *Cantuo volcanicae-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 11, Table 2, col. 5)

6. *Paronychio microphyllae-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 5, Table 2, col. 6)

Neoraimondio arequipensis-Weberbauerocerion rauhii all. nov. (*Lectotypus*: *Weberbauerocereo rauhii-Browningietum candelaris* Galán de Mera et al. 2009)

In the synoptic table (Table 3) the following associations as described by Galán de Mera et al. (2009, 2011b) were combined. In general, diagnostic species are missing, except for *Browningia viridis* in the last mentioned association. Further research is needed to clarify the presence of the associations in this alliance.

Weberbauerocereo rauhii-Browningietum candelaris Galán de Mera et al. 2009
  larreetosum divaricatae Galán de Mera et al. 2011
Armatocereo riomajensis-Neoraimondietum arequipensis Galán de Mera et al. 2011
Weberbauerocereo rauhii-Corryocactetum brevistyli Galán de Mera et al. 2009
Neoraimondio arequipensis-Browningietum viridis Galán de Mera et al. 2011

Corryocaction brevistyli Galán de Mera & Vicente Orellana 1996 (*Typus*: *Oreocereo tacnaensis-Corryocactetum brevistyli*, type 9, Table 2 in Galán de Mera & Vicente Orellana 1996)

7. *Balbisio weberbaueri-Ambrosietum artemisioidis* Galán de Mera et al. 2011 (*Typus*: Table 4, col. 1 in Galán de Mera et al. 2011b)
8. *Aloysio spathulatae-Corryocactetum brevistyli* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 2, Table 2, col. 8.1)

8.1 *oenotheretosum rubidae* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 2, Table 2, col. 8.1)

8.2 *adesmietosum augusti* Montesinos-Tubée et al. 2015 (*Typus*: Rel. 9, Table 2, col. 8.2)

Weberbauerocereo weberbaueri-Corryocactetum brevistyli Galán de Mera & Gómez Carrión 2001

Corryocacto aurei-Browningietum candelaris Galán de Mera & Vicente Orellana 1996

Oreocereo tacnaensis-Corryocactetum brevistyli Galán de Mera & Vicente Orellana 1996

Grindelio bolivianae-Corryocactetum puquiensis Galán de Mera & Gómez Carrión 2001

Diplostephio tacorensis-Parastrephietum lepidophyllae corryocactetosum brevistyli Galán de Mera et al. 2003

Weberbauerocereo rauhii-Corryocactetum brevistyli crotonetosum ruiziani Galán de Mera et al. 2009

Vegetation description (Tables 2 and 3; Appendices 1–8)

The class *Opuntietea sphaericae* and order *Oreocereo leucotrichi-Neoraimondietalia arequipensis* represent the cactus formations in dry regions of South America, especially in the Andes of central and South Peru.

Diagnostic species of the class: *Opuntia sphaerica.* Diagnostic species of the order: *Ambrosia artemisioides, Armatocereus riomajensis, Corryocactus aureus, Haageocereus platinospinus, Oreocereus hempelianus, Browningia candelaris* and *Tarasa operculata.*

The new alliance ***Ambrosio artemisiodis-Weberbauerocerion weberbaueri*** is characterized by the co-occurrence of the perennial shrub *Ambrosia artemisioides* and the columnar cactus *Weberbauerocereus weberbaueri* distributed in South Peru (Galán de Mera & Vicente Orellana 1996; Brako & Zarucchi 1993). It is restricted to dry regions, with precipitation below 80mm/year, covered by vegetation with abundant cacti accompanied by few other xerophytes. *Weberbauerocereus weberbaueri* and *Exodeconus pusillus* are character species of this alliance. The *Ambrosio artemisioidis-Weberbauerocerion weberbaueri* is differentiated against the *Neoraimondio arequipensis-Weberbauerocerion rauhii* and *Corryocaction brevistyli* by species like *Solanum peruvianum, Cristaria multifida, Fuertesimalva chilensis, Plantago limensis, Aristida adscensionis, Exodeconus pusillus*. Also annual species turned out to be differential.
The *Ambrosio artemisiodis-Weberbauerocerion weberbaueri* includes the previously described *Weberbauerocereo weberbaueri-Browningietum candelaris* Galán de Mera & Vicente Orellana 1996 and six other new associations.

Ecology and distribution: In our study this alliance represents communities on sandy soils and sedimentary volcanic soils with quartzite and sandstone screes mixed with fine gravel on barren hillsides with xerophytic vegetation between 2000 and 2900 m. This alliance is representative of the vegetation units occurring in the Arequipa city boundary zones where the abundance of *Weberbauerocereus weberbaueri* is characteristic.
Species of the *Ambrosio artemisiodis-Weberbauerocerion weberbaueri* are highly indicative of dry environmental conditions. For instance *Browningia candelaris, Haageocereus platinospinus, Hoffmannseggia viscosa* var. *egena, Montiopsis cumingii* and *Weberbauerocereus weberbaueri* are species that occur on dry slopes in the Arequipa region and can also occur in Moquegua and Tacna regions (Brako & Zarucchi 1993; http:/www.tropicos.org). *Weberbauerocereus weberbaueri* is endemic to the Arequipa province and has not been found outside this region (Rauh 1958; Ritter 1981; Aragón 1982; Brako & Zarucchi 1993; Sahley 1996; Mariño et al. 1998; Arakaki 2003). Despite the high abundance of annual and biannual species encountered within the *Weberbauerocereus weberbaueri* communities, it is most unlikely that the majority of character species of the associations occur in scrubland units. In contrast, species of the *Corryocaction brevistyli* are highly indicative of subhumid conditions. They occur on clay soils associated with scrubland vegetation on volcanic slopes in the north and northwest of Arequipa province in boundary with the Prepuna and Puna. Here several species have been identified that also occur in the highland communities, for example: *Adesmia* spp., *Balbisia weberbaueri, Calceolaria inamoena, Chersodoma* spp., *Diplostephium meyenii,*

Table 2. *Typus* relevés of all the new associations and subassociations.

	1.1	1.2	1.3	2.1	2.2	2.3	2.4	3.1	3.2	4	5	6	8.1	8.2
Relevé number	6	21	30	6	17	32	39	13	28	4	11	5	2	9
Area (m2)	25	25	25	25	25	25	25	25	25	25	25	25	64	64
Altitude (m) x 10	2	2	2	2	2	2	2	2	2	2	2	2	2	3
	0	4	0	7	7	4	5	4	3	6	3	8	8	0
	2	7	3	3	0	5	9	6	4	0	4	5	0	4
Slope (°)	40	30	45	25	6	20	10	40	20	7	14	25	45	10
Aspect	S	S	S	S	S	E	N	NNE	W	SE	WSW	E	N	N
Species #	11	10	11	16	18	19	8	19	16	15	13	19	23	26
Character species of class and order														
Haageocereus platinospinus	5		2											
Opuntia sphaerica	2	3			4	2				4		3	2	5
Ambrosia artemisioides			3	2	3	2		5	5	5	5	6	2	
Armatocereus riomajensis														
Tarasa operculata		2		3	3	1	2	4		4		4	1	
Oreocereus hempelianus				3							2			
Corryocactus aureus														2
Ambrosio artemisioidis-Weberbauerocerion weberbaueri														
Weberbauerocereus weberbaueri			3	5	6	4	4	5	5	6	4	6		
Exodeconus pusillus	1		1			5	2			1		2		
1. Weberbauerocereo weberbaueri-Browningietum candelaris														
Browningia candelaris	5		3											
Calandrinia ciliata	1		1						1					
1.1 haageocereetosum plurifoli														
Haageocereus pluriflorus	1													
Nolana spergularoides	1													
1.2 onoseridetosum odoratae														
Onoseris odorata		2												
Euphorbia hinkleyorum		2												
Drymaria divaricata		1												
Plantago limensis		1												
Cystopteris fragilis		1												
1.3 neoraimondietosum arequipensis														
Neoraimondia arequipensis			4											
Tiquilia paronychioides			1											
Tetragonia ovata			1											
2. Senecioni yurensis-Weberbauerocereetum weberbaueri														
Senecio yurensis					2	3								
Neuontobotrys lanata				2	1									
Mostacillastrum pectinifolium					1									
2.1 oenotheretosum verrucosae														
Oenothera verrucosa				2										
Cuscuta cockelerii				1										
2.2 chionopappetosum benthamii														
Chionopappus benthamii					6									
Dipyrena glaberrima					3									
Gaya mollendoensis														
Tarasa rahmerii					1									
2.3 ephedretosum americanae														
Ephedra americana						5		2				2		2
Hoffmannseggia prostrata						1								
Mastigostyla cyrtophylla						1								
Bryantiella glutinosa						1								
Mirabilis elegans						2								
2.4 eremodrabetosum schulzii														
Eremodraba schulzii							4							
Chorizanthe commisuralis							1							
3. Euphorbio apurimacensis-Weberbauerocereetum weberbaueri														
Euphorbia apurimacensis								5	2					
Puya cylindrica								5						

	1.1	1.2	1.3	2.1	2.2	2.3	2.4	3.1	3.2	4	5	6	8.1	8.2
3.1 kramerietosum lappacea														
Fuertesimalva chilensis								1						
Krameria lappacea								2						
Anredera diffusa								2						
Astrolepis sinuata								1						
Aloysia spathulata								4						
Alternanthera halimifolia								3						
Myriopteris myriophylla								1						
Gaya mollendoensis								4						
Gaya mollendoensis								4						
3.2 jatrophetosum macranthae														
Jatropha macrantha									5					
Cystopteris fragilis									1					
Cheilanthes fractifera									1					
Senecio yurensis									4					
4. Lycio distichi-Weberbauerocereetum weberbaueri														
Lycium distichum										2				
Aphyllocladus denticulatus										4				
5. Cantuo volcanicae-Weberbauerocereetum weberbaueri														
Cantua volcanica											2			
Tecoma fulva subsp. *arequipensis*											3			
6. Paronychio microphyllae-Weberbauerocereetum weberbaueri														
Paronychia microphylla var. *arequepensis*												2	2	
Dalea exilis										1		3		
Pteromonnina ramosa												2		
Corryocaction brevistyli														
Corryocactus brevistylus													5	4
Balbisia weberbaueri													2	4
Gochnatia arequipensis													4	5
Junellia arequipense														5
8. Aloysio spathulatae-Corryocactetum brevistyli														
Senecio subcandidus													2	3
Aloysia spathulata													3	2
Senna birostris var. *arequipensis*														2
8.1 oenotheretosum rubidae														
Kageneckia lanceolata													5	
Croton ruizianus													4	
Lantana scabiosiflora													2	
Heliotropium toratense													2	
Oenothera rubida													1	
Vasquezia oppositifolia													1	
Bomarea ovata													1	
Tigridia arequipensis													1	
8.2 adesmietosum augusti														
Adesmia augusti														2
Pectocarya anomala														1
Austrocylindropuntia subulata														4
Diplostephium meyenii														3
Companions														
Allionia incarnata											2			
Aristida adscencionis	1	2	1	2	1	4		2			5	1		1
Bowlesia sodiroana													1	1
Cheilanthes arequipensis									2					
Cheilanthes pruinata													2	2
Chenopodium petiolare				*1*							2			
Cristaria multifida	1	1				1	2			2				
Cryptantha parviflora			1											
Drymaria divaricata									1					1
Eragrostis nigricans									1		5	3		2
Eragrostis peruviana													3	2
Facelis plumosa														1
Fuertesimalva chilensis					1					2		1		
Galium aparine														1

	1.1	1.2	1.3	2.1	2.2	2.3	2.4	3.1	3.2	4	5	6	8.1	8.2
Gamochaeta americana												1		
Hoffmannseggia viscosa var. *egena*					1									
Pteromonnina macbridei				1										
Montiopsis cumingii										2				
Mostacillastrum gracile												1		1
Nama dichotoma				1	1			1	1			1		
Oxalis megalorrhiza				1	2		2							
Quinchamalium procumbens												3		
Pectocarya lateriflora				1	2	2			1		3		1	
Pellaea ternifolia												1		1
Plantago linearis				2							3			
Portulaca pilosa						1					2			1
Schkuhria multiflora						1								
Senecio sp. (# 3344)	1					1			1	1				
Solanum paposanum				1						2				
Solanum peruvianum	1	1			2	1		2	4			2		
Tagetes multiflora				2	1				1	1		1	1	
Tarasa rahmerii								2			2		1	1
Tiquilia elongata						2	5							

Gochnatia arequipensis, Kageneckia lanceolata, Lupinus spp., *Junellia arequipense.* The ecology of *Corryocactus brevistylus* has been studied by some authors (Aragón 1982; Galán de Mera & Vicente Orellana 1996; Cáceres et al. 2000; Galán de Mera & Gómez Carrión 2001; Mauseth et al. 2002). We have identified the distribution of the units within the *Corryocaction brevistyli* ranging between an elevation of 2800 and 3260 m in the Arequipa province. According to Brako & Zarucchi (1993), the species also occurs in the Puno region.

This is the first time that *Neuontobotrys lanata, Paronychia microphylla* var. *arequipensis* and *Senecio yurensis,* have been referred to in a phytosociological context. Apart from the reference by Brako & Zarucchi (1993), Al-Shehbaz (2006) and León et al. (2006), these biannual species have considerable abundance in the Arequipa region and we are not aware of their occurrence in other vegetation series.

1. *Weberbauerocereo weberbaueri-Browningietum candelaris* (Table 2, col. 1.1–1.3 and Table 3, col. 1. Appendix 1, Fig. 3)

Physiognomy and composition: The vegetation of this association grows on widely distributed rocky scree with pockets of sand. Thirty-one relevés were made, yielding a total of 69 species. As in the previous units, annual grasses and herbs dominate after sufficient rainfall. The cacti in this association are columnar (up to 4 m high), not prostrate.

Syntaxonomy: Diagnostic species for this association are the columnar species *Weberbauerocereus weberbaueri* and *Browningia candelaris* with the herb *Calandrinia ciliata* and with lower frequency also species like *Euphorbia hinkleyorum*, *Nolana spergularoides* and *Onoseris odorata*. It is further differentiated by the prostrate *Haageocereus platinospinus*.

Ecology and distribution: The association is located in the thermotropical and mesotropical belts between 2020 and 2500 m on the sandy and rocky dry slopes of the districts of Uchumayo and Polobaya in the Arequipa province.
The columnar cactus *Weberbauerocereus weberbaueri* grows in areas with sandy soils and frequent wind gusts that transport sand which eventually builds dunes, and is distributed over the western arid slopes and hills between the Chili River near Uchumayo district and the Yura River. The vegetation cover varied from 15% cover of cacti to up to 70% cover of the annual vegetation. *Tiquilia elongata* forms communities with low cover in the lomas formations (Galán de Mera et al. 2011a).
The *Weberbauerocereo weberbaueri-Browningietum candelaris* (Galán de Mera et al. 2009, 2011b) is an association described for the Arequipa province apparently based on only one relevé with eight species. No full table was found for this unit. We consider community 1 as derived from our own classification to be sufficiently similar to the relevé mentioned above, and consequently adopted the association name (Table 3, communities 1–2). The relevé by Galán de Mera et al. (2011b) originates from the same area in the Uchumayo district. Also in the DCA and the dendrogram (Fig. 10, 11) are clustered with five more associations, characterized by *Weberbauerocereus weberbaueri* and *Exodeconus pusillus*. Consequently we have decided to distinguish a separate alliance. This is also supported by the similarity in ecological conditions and altitudinal distribution. It differs considerably from the Corryocaction brevistyli in terms of ecology, species composition and elevation.

1.1 *haageocereetosum pluriflori* (Table 3, col. 1. Appendix 1)
Physiognomy and composition: The low frequency and cover of annual species characterise this subassociation for its proximity to the very dry semi-desert. Xeric species dominate the slopes, especially those with columnar forms like *Browningia candelaris,* and with lower frequency *Weberbauerocereus weberbaueri*. Prostrate cactae with constancy are *Haageocereus platinospinus* and *H. pluriflorus.*
Syntaxonomy: The *haageocereetosum pluriflori* is differentiated against the other two subassociations of the *Weberbauerocereo weberbaueri-Browningietum candelaris* by *Haageocereus pluriflorus* and the annual *Nolana spergularoides*.
Ecology and distribution: The subassociation is part of the xerophytic vegetation series distributed over the driest slopes of Uchumayo (2020 m, Uchumayo district). The ecosystem is much degraded: waste plastic has become trapped by wind action in the cacti spines, a phenomenon known as “witches’ knickers”.

1.2 *onoseridetosum odoratae* (Table 3, col. 1. Appendix 1. Fig. 3)
Physiognomy and composition: Apart from biennial herbs, grasses, and succulents, there are numerous annual species, many of them endemic. The columnar cacti can grow up to 4 m tall.

Syntaxonomy: The *onoseridetosum odoratae* is differentiated by many species like *Onoseris odorata, Euphorbia hinkleyorum*, *Urocarpidium albiflorum, Armatocereus riomajensis, Plantago linearis, P. limensis, Oxalis* sp. (# 3537), *Mirabilis elegans* and *Senecio yurensis*.
Ecology and distribution: This subassociation occurs on dry, stony slopes and is characteristic of the thermotropical bioclimate. In normal years, these slopes are assumed to receive a mean precipitation of between 2–10 mm, but it is estimated that in 2012 50 mm of rain fell on.

1.3 *neoraimondietosum arequipensis* (Table 3, col. 1. Appendix 1)
Physiognomy and composition: As in the previous units, annual grasses and herbs dominate after sufficient rainfall. The cacti in this subassociation are columnar (up to 4 m high), not prostrate.
Syntaxonomy: This subassociation is differentiated by the columnar *Neoraimondia arequipensis,* the yellow-flowered *Exodeconus flavus, Tetragonia ovata, Leptoglossis acutiloba* and the purplish-flowered *Tiquilia grandiflora* and by the relatively high cover and frequency of the character species of the alliance *Weberbauerocereus weberbaueri.*
Ecology and distribution: The vegetation of this subassociation grows on widely distributed rocky scree with pockets of sand, located between 2020 and 2100 m on the dry slopes of Uchumayo district.
The subassociations *haageocereetosum pluriflori*, *onoseridetosum odoratae* and *neoraimondietosum arequipensis* of the association *Weberbauerocereo weberbaueri-Browningietum candelaris* are characterized by the presence of several columnar and prostrate cacti together with many annual grasses and herbs emerging after the rain event, and -with the exception of the woody *Ambrosia artemisioides* and the biannual *Senecio yurensis*- particularly also by the absence of shrubs. These xerophytic communities are strongly influenced by sand deposits, and every year they experience high radiation in areas that are unlikely to receive precipitation (except during ENSO and other extreme climatic events like the one occurred in 2012). The vegetation is structured by columnar cacti (species of *Browningia, Neoraimondia, Armatocereus, Weberbauerocereus*) and by decumbent species such as *Oreocereus hempelianus, Haageocereus platinospinus* (occasionally accompanied by *H. pluriflorus*) co-occurring with the globular *Opuntia sphaerica.* The biannual semi-woody *Tiquilia elongata* (Boraginaceae) establishes on drift sands that are prone to wind erosion. After the first precipitation, it rapidly germinates together with *Aristida adscensionis* and *Cristaria multifida*. *Tiquilia elongata,* an endemic species (León & Sánchez 2006), is well distributed on the arid hills in southern Peru (Moore et al. 2006; Schwarzer et al. 2010; Galán de Mera et al. 2011b). The cactus *Browningia candelaris* is frequent in these ecosystems and associated with *Opuntia sphaerica* and *Haageocereus platinospinus*.

2. *Senecioni yurensis-Weberbauerocereetum weberbaueri* (Table 3, col. 3. Appendix 2. Fig. 4)

Physiognomy and composition: The vegetation is composed of one columnar cactus (*Weberbauerocereus weberbaueri*) and dwarf shrubs of *Ambrosia artemisioides, Senecio yurensis* and *Tarasa operculata.* The herb layer is characterized by the high frequency of *Cristaria multifida, Exodeconus pusillus* and *Tiquilia elongata.* The columnar cactus *Weberbauerocereus weberbaueri* reaches up tp 5 m in height. The vegetation is dominated by some shrubs and annual herbs.

Syntaxonomy: Character species are *Senecio yurensis, Neuontobotrys lanata*, and several endemic species with low frequency only, like *Mostacillastrum pectinifolium, Chionopappus benthamii, Gaya moyendoensis, Loxanthocereus jajoianus, Mastigostyla cyrthophylla, Eremodraba schulzii, Orobanche weberbaueri* and *Tarasa thyrsoidea. Oreocereus hempelianus* is differential against the other associations of this alliance. Within our study this association contains the highest endemic species diversity.

Ecology and distribution: The vegetation of the association occurs in the thermotropical and mesotropical belts between 2450 and 2700 m on dry sandy rocky slopes and gravel soils across the district of Uchumayo and Yura in the Arequipa province.

The association *Senecioni yurensis-Weberbauerocereetum weberbaueri* is well represented on sedimentary soils on the lower slopes of the Chachani volcano, between the Yura and Chili rivers, at elevations between 2450 and 2700 m. The *Weberbauerocereus weberbaueri* communities in this locality are more strongly influenced by higher amounts of precipitation than the communities on the southwestern hills. They contain 61 species, with many endemics and few shrubby species and more dominance of annual herbs. Other cacti species are less frequent where the higher frequency of the prostrate *Opuntia sphaerica* is more prominent. *Weberbauerocereus weberbaueri* remains constant in the landscape, accompanied by *Ambrosia artemisioides*. Among the endemics, *Mostacillastrum pectinifolium* is a species restricted to Arequipa province (Al-Shehbaz 2006) together with the monotypic shrub *Chionopappus benthamii* reported from North Peru (Leiva Gonzáles et al. 2008) and recently from South Peru (botanical collections at USM herbarium), which is presumably a new subspecies yet to be confirmed.

2.1 *oenotheretosum verrucosae* (Table 3; Table 2: 2.1; 3: 3. Appendix 2)

Physiognomy and composition: Characterized by the abundance of *Weberbauerocereus weberbaueri* together with *Oreocereus hempelianus* and *Oenothera verrucosa*. Other differences include the absence of species proper to the puna and being more characteristic of the arid communities with dominance of few perennials such as *Ambrosia artemisioides, Oreocereus hempelianus* and *Tarasa operculata*. The annual part of the vegetation is rich in species, and its cover varies between the relevés.

Syntaxonomy: The *oenotheretosum verrucosae* is differentiated from the other subassociations by *Oenothera verrucosa, Cuscuta cockelerii, Atriplex rotundifolia* and *Cistanthe calycina*.

Ecology and distribution: The vegetation of the subassociation grows on superficial rocky soils partly covered by clayey sand, at elevations between 2610–2900 m. in Yura district.

2.2 *chionopappetosum benthamii* (ab. 3, col. 3. Appendix 2. Fig. 4)

Physiognomy and composition: Characterized by the abundance of *Weberbauerocereus weberbaueri* in all relevés. Other differences include the similarity to the scrubland vegetation with *Corryocactus brevistylus.*

Syntaxonomy: Differential species are *Chionopappus benthamii, Dipyrena glaberrima, Gaya mollendoensis, Tarasa operculata Bowlesia sodiroana, Fuertesimalva chilensis, Myriopteris myriophylla, Cheilanthes pruinata, Cheilanthes arequipensis* and *Solanum medians.*

Ecology and distribution: The vegetation of this subassociation grows on slopes covered by clayey sand and abundance of rocks and stones at elevations between 2670 and 2700 m.

2.3 *ephedretosum americanae* (Table 3, col. 3. Appendix 2)

Physiognomy and composition: By comparison with the *eremodrabaetosum schulzii*, the herb layer is more species-rich and columnar cacti are more abundant; *Weberbauerocereus weberbaueri* is always present.

Syntaxonomy: This subassociation is differentiated by *Ephedra americana* and by the annuals *Hoffmannseggia prostrata, Mastigostyla cyrtophylla*, and the endemic subshrub *Tarasa thyrsoidea.* Further differentiating against the other subassociations are species like *Bryantiella glutinosa, Cistanthe celosioides, Mirabilis elegans* and *Montiopsis cumingii.*

Ecology and distribution: The vegetation of the subassociation occurs at a mean elevation of 2450 m on sandy dry rocky slopes across the Congata road to Cerro Verde (Uchumayo district). This subassociation represents the vegetation of the driest hills southwest of Arequipa city.

2.4 *eremodrabetosum schulzii* (Table 3, col. 3. Appendix 2. Fig. 4)

Physiognomy and composition: The near absence of cacti is characteristic, but small annual herbs and annual shrubs (average height 30 cm) are more frequent.

Syntaxonomy: The subassociation has three differential species: the annual herb *Chorizanthe commisuralis*, the annual shrub *Eremodraba schulzii*, and the holoparasitic herb *Orobanche weberbaueri* that is considered as to parasitize cacti and shrub roots. It is further characterized by the absence of cacti including *Weberbauerocereus weberbaueri* and *Opuntia sphaerica*.

Ecology and distribution: The vegetation of this subassociation grows on arid soils with sandstone gravel in the arid hills of Yura district at an elevation of around 2600 m.

3. *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* (Table 3, col. 4. Appendix 3. Fig. 5)

Physiognomy and composition: A total of 68 species were recorded, among which many endemics from the Arequipa region. Shrubs are more frequent than in the preceding communities. The diagnostic shrub *Euphorbia apurimacensis* and *Jatropha macrantha* (both endemic) can reach up to 2 m in height. Globular cacti are also common, together with many annual herbs and few dwarf shrubs. Cacti are mostly represented by the constant *Weberbauerocereus weberbaueri* and, with low frequency, also by *Browningia candelaris, Neoraimondia arequipensis*, and *Opuntia sphaerica*, and by the columnar cactus *Corryocactus brevistylus.* Much of the vegetation consists of annual species.

Syntaxonomy: The diagnostic species *Euphorbia apurimacensis* is very frequent. Other diagnostic species with lower frequency are *Puya cylindrica, Astrolepis sinuata, Krameria lappacea* and *Jatropha macrantha.*

Ecology and distribution: The vegetation of this association occurs in the mesotropical belt and is widely distributed on steep granitic slopes with sandy soils. This vegetation grows on the extensive dry rocky slopes on the left bank of Socabaya River south of Arequipa city (Hunter, Socabaya, and Yarabamba district), at an elevation of 2230–2740 m.

For the *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* we identified one of the highest numbers of species endemic to Peru which are widely distributed in the arid rocky hills and ravines south of Arequipa city. Species diversity is high, with 68 species, of which 65 are native, including 16 endemics, and only 49 native species. Three species are introduced. The endemic shrubs *Euphorbia apurimacensis* and *Jatropha macrantha* form a dense vegetation structure together with *Weberbauerocereus weberbaueri* and the native *Ambrosia artemisioides*.

3.1 *kramerietosum lappaceae* (Table 3, col. 4. Appendix 3)

Physiognomy and composition: This subassociation is charecterised by a high species diversity; fifty species were recorded from 15 relevés. *Weberbauerocereus weberbaueri* has high constancy and cover and occurs in combination with *Euphorbia apurimacensis, Tarasa operculata*, and *Ambrosia artemisioides.*

Syntaxonomy: This subassociation is differentiated by *Krameria lappacea*, a prostrate shrub with grayish leaves and purple flowers and by species like *Fuertesimalva chilensis, Anredera diffusa, Astrolepis sinuata, Aloysia spathulata, Alternanthera halimifolia, Gaya mollendoensis, Pellaea ternifolia, Schkuhria multiflora* and *Solanum paposanum.*

Ecology and distribution: The xerophytic *kramerietosum lappaceae* grows between 2460 and 2740 m, on the arid rocky slopes of the hills west and southwest of Socabaya and Yarabamba districts with occurrence on sandy steep slopes between large boulders.

3.2 *jatrophetosum macranthae* (Table 3, col. 4. Appendix 3)
Physiognomy and composition: The cover of columnar cacti and of annual vegetation is high. The vegetation includes sprawling and succulent shrubs, annual herbs, grasses, and ferns.
Syntaxonomy: The main differential species is *Jatropha macrantha*, a euphorbious succulent shrub with palmate leaves and red flowers. Other differential species (annuals) are: *Cystopteris fragilis, Cheilanthes fractifera, Mentzelia scabra* subsp. *chilensis*, *Portulaca pilosa, Stipa plumosa and Allionia incarnata. Senecio yurensis*, a character species at the alliance level, is also differentiating against the kramerietosum lappaceae.
Ecology and distribution: The *jatrophetosum* vegetation grows on rocky slopes with sandy soil, between 2320 and 2580 m, on the southern hills southwest of Socabaya, Jacobo Hunter, and Tiabaya districts.
Although there is some floristic affinity and ecologic similarity with the *Weberbauerocereo rauhii-Browningietum candelaris* (Galán de Mera et al. 2009), there is a major difference in species composition and in the distribution of columnar and prostrate cacti. The absence of *Euphorbia apurimacensis* is characteristic on the lower slopes (<2200 m) of our study area, but this species is well represented in the *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* between 2230–2740 m. Galán de Mera et al. (2009) refer to the plant communities growing on the slopes of the Colca and Cotahuasi rivers in the north of Arequipa province. These communities occur in different hydrographic basins and are characterized by the constancy of the vicariant *Weberbauerocereus rauhii,* absent from our communities.

4. *Lycio distichi-Weberbauerocereetum weberbaueri* (Table 3, col. 5. Appendix 4. Fig. 6)
Physiognomy and composition: The physiognomy of the vegetation is determined by the continuous high cover of the columnar cactus *Weberbauerocereus weberbaueri.* The globular cactus *Opuntia sphaerica* is less abundant.
Syntaxonomy: Character species are *Lycium distichum* and with lower frequency also *Aphyllocladus denticulatus.* It is further differentiated against the other associations of this alliance by *Montiopsis cumingii*.
Ecology and distribution: This vegetation grows between 2600 and 2930 m, the upper limit of the distribution of *Weberbauerocereus weberbaueri* in the study area. It is recorded from the summits of the hills from the Chapi River in the Polobaya district, developing on sandy slopes with carbonates and without rocks of 6–7° with a southerly aspect. The association occurs in the mesotropical belt.

In the phytosociological reference for *Lycium distichum* by Galán de Mera et al. (2011b), the association Lycio distichi-Baccharidetum uniflorae is described based on three réleves in dry ecosystems with heavy anthropic influence and absence of cacti. We consider this unit as not comparable to our study based on species composition and ecology. *Lycium distichum* is found from sea level up to 3500 m in southern Peru and northern Chile (Brako & Zarucchi 1993). This is also true for the asteraceous shrub *Aphyllocladus denticulatus*, which is mentioned by Schwarzer et al. (2010) from the arid pumice slopes of the Huaynaputina volcano in Moquegua, South Peru.

5. *Cantuo volcanicae-Weberbauerocereetum weberbaueri* (Table 3, col. 6. Appendix 5. Fig. 7ab, 9)

Physiognomy and composition: Thirty-nine plant species (xerophytes, annual herbs, shrubs and one tree species) were found in this association. The columnar *Weberbauerocereus weberbaueri* dominates the landscape, with individual specimens attaining up to 4 m in height. Shrubs are common. *Tecoma fulva* subsp. *arequipensis* is present with low frequency. The tree *Prosopis laevigata* var. *andicola* was found in only one relevé, where its cover was relatively high and individuals were 3–6 m tall. The mixture of endemic, native and introduced species is characteristic on these slopes, and vegetation cover can reach 100% after high precipitation (about 300 mm recorded in 2012).

Syntaxonomy: This association contains the following diagnostic species: *Cantua volcanica, Tecoma fulva* subsp. *arequipensis* and with very low presence class also *Helogyne apaloidea, Prosopis laevigata* var. *andicola*. It is further differentiated by the class characteristics *Corryocactus aureus, Chenopodium incisum, Encelia canescens* and *Heterosperma diversifolium.*

Ecology and distribution: The vegetation of the *Cantuo volcanicae-Weberbauerocereetum weberbaueri* occurs in the mesotropical belt and represents a relict of the natural vegetation of Arequipa before the city was built (Fig. 10). It grows on degraded land, where both endemic and introduced species co-occur in the high cover of *Weberbauerocereus weberbaueri.* Sixteen relevés were made at an elevation between 2305 and 2345 m. As a consequence of urbanization and harvesting for fuel, the native legume tree *Prosopis laevigata* var. *andicola* is rapidly declining and is threatened with extinction. The vegetation of this association occurs in the district of Socabaya at the boundary with the district of José Luis Bustamante y Rivero and it presumably extends to the semi-arid slopes in the districts of Yarabamba, Sogay, and Quequeña. In contrast, the *Schino mollis-Tecometum arequipensis* Galán de Mera et al. 2009 (Galán de Mera et al. 2009) represented for sandy soils in ravine slopes near the city of Arequipa, lacks the presence of the columnar cactus *Weberbauerocereus weberbaueri* and other species here reported.

Figure 3. *Weberbauerocereo weberbaueri-Browningietum candelaris onoseridetosum odoratae* in Chapi, Polobaya district at 2500 m.

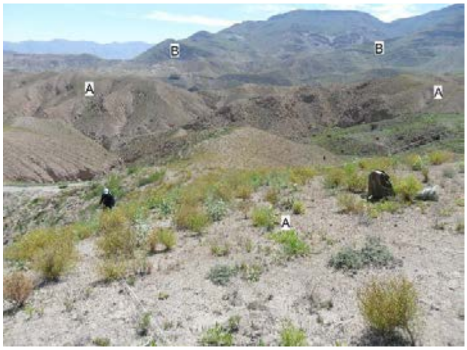

Figure 4. Slopes in the Yura district where the *Senecioni yurensis-Weberbauerocereetum weberbaueri eremodrabetosum schulzii* (A) and *chionopappetosum benthamii* (*typicum*) (B) develops at 2600–2700 m.

Figure 5. *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* with the subassociation *jatrophetosum macranthae* on the rocky slopes of Jacobo Hunter and Tiabaya, at 2300–2560 m. The city of Arequipa can be seen in the valley and the Chachani volcano at the top right side.

Figure 6. Slopes in Chapi, Polobaya district at 2600 m with (A) *Lycio distichi-Weberbauerocereetum weberbaueri* and (B) *Weberbauerocereo weberbaueri-Browningietum candelaris onoseridetosum odoratae*.

The *Cantuo volcanicae-Weberbauerocereetum weberbaueri* and the *Schino mollis-Tecometum arequipensis* (Galán de Mera et al. 2009) differ greatly in species composition. The first association occurs in ravines and rocky slopes along water channels where columnar cactae are absent. The *Prosopis pallida* community (=*Prosopis laevigata* var. *andicola*), as described by Galán de Mera et al. (2009), is only based on one relevé with five species in which even *Weberbauerocereus weberbaueri* is missing.

6. *Paronychio microphyllae-Weberbauerocereetum weberbaueri* (Table 3, col. 7. Appendix 6)

Physiognomy and composition: Within the distribution area of *Weberbauerocereus weberbaueri*, this association dominates the lower slopes of the Misti volcano. Columnar

cacti dominate the slopes together with dwarf shrubs, annual herbs and grasses. On the sedimentary volcanic soils the vegetation cover is high. Only few annual and perennial shrubs are part of the vegetation.
Syntaxonomy: The association of *Paronychio microphyllae-Weberbauerocereetum weberbaueri* is characterized by *Paronychia microphylla* var. *arequipensis* (the variety *arequipensis* is endemic of the Arequipa region), *Dalea exilis, and Pteromonnina ramosa.* Differential species are *Mostacillastrum gracile, Gamochaeta purpurea, Spergularia fasciculata* and *Quinchamalium procumbens*.
Ecology and distribution: The association grows in the mesotropical belt between 2700 and 2850 m on sedimentary volcanic soils, in areas where precipitation is likely to be more abundant compared to the other localities within the distribution area of *Weberbauerocereus weberbaueri*. It occurs on the slopes of the Misti volcano, at the boundary between the Chilina valley and the populated district of Alto Selva Alegre, Mariano Melgar and Miraflores, northeast of Arequipa city.

Alliance: ***Neoraimondio arequipensis-Weberbauerocerion rauhii*** (Table 3, col. 8–12)
Based on previously published syntaxa (Galan de Mera et al. 2009, 2011b), our synoptic table shows a unit clearly distinguished by the character species *Weberbauerocereus rauhii* and the columnar cactus *Neoraimondia arequipensis.* This unit is here described as a new alliance. *Armatocereus riomajensis* is most probably also a character species of this alliance as, apart from *Armatocereo riomajensis-Euphorbietum apurimacensis* in Appendix 1, it is only highly frequent in the *Neoraimondio-Weberbauerocerion*. Our comparison with previously published syntaxa revealed the necessity to distinguish one more new alliance for which we introduce the new name *Neoraimondio arequipensis-Weberbauerocerion rauhii*, grouping five associations described by Galán de Mera et al. (2009, 2011b).
It is negatively differentiated against the *Ambrosio-Weberbauerocerion* by the absence of *Tarasa operculata, Senecio yurensis, Cantua volcanica, Paronychia microphylla* var. *arequepensis* and *Solanum peruvianum,* which are constant and common in the *Ambrosio-Weberbauerocerion*. Furthermore, the new alliance differs from *Corryocaction brevistyli* by the absence of shrubs like *Balbisia weberbaueri, Diplostephium meyenii* and *Grindelia tarapacana.* For the comparison with the other alliances, no annual species were used in the analysis.
Weberbauerocereus rauhii is distributed in South Peru (Galán de Mera et al. 2009, 2011b; Brako & Zarucchi 1993). It is restricted to dry regions, with scarce precipitation, on steep alluvial slopes with mesotropical arid/semi-arid bioclimate, covered by vegetation with abundant cacti accompanied by few xerophytes. It is distributed in interandean valleys from the Colca and Cotahuasi canyons (Arequipa province), and in the Moquegua and Tacna provinces. Galán de Mera et al. (2009) described the association of Weberbauerocereo rauhii-Corryocactetum brevistyli for the Colca and Cotahuasi canyons (in the north of the Arequipa department). This association is absent in Arequipa

province. Also other associations with *Weberbauerocereus rauhii* are absent from our study area, its distribution is more easterly, towards areas that receive more precipitation. *W. rauhii* becomes replaced by *W. weberbaueri*, which turn out to be dominant and very characteristic in association with *Euphorbia apurimacensis* and *Jatropha macrantha.*
In Table 3 the following associations as described by Galán de Mera were grouped together within the new alliance. In general however, diagnostic species are missing, except for *Browningia viridis* in the last mentioned association. Although listed below the associations, are not further discussed as clearly further research is needed to clarify the position of the associations in this alliance.

- Table 3, comm. 8: *Weberbauerocereo rauhii-Browningietum candelaris larreetosum divaricatae* Galán de Mera et al. 2011
- Table 3, comm. 9: *Armatocereo riomajensis-Neoraimondietum arequipensis* Galán de Mera et al. 2011
- Table 3, comm. 10: *Weberbauerocereo rauhii-Browningietum candelaris* Galán de Mera et al. 2009
- Table 3, comm. 11: *Weberbauerocereo rauhii-Corryocactetum brevistyli* Galán de Mera et al. 2009
- Table 3, comm. 12: *Neoraimondio arequipensis-Browningietum viridis* Galán de Mera et al. 2011

Alliance: ***Corryocaction brevistyli***
The alliance represented by the columnar cactus *Corryocactus* occurs in semi-dry regions where xerophyte vegetation is abundant and predominant. According to the floristic affinity a number of communities could be assigned to the *Corryocaction brevistyli*, including several previously described associations and one new association.
Syntaxonomy: The *Corryocaction brevistyli* is characterized by *Corryocactus brevistylus, Balbisia weberbaueri, Gochnatia arequipensis* and *Junellia arequipense* and by the differential species *Diplostephium meyenii* and *Grindelia tarapacana*.
Ecology and distribution: The alliance represented by the columnar cactus *Corryocactus brevistylus* is distributed from Peru to North Chile (Galán de Mera & Vicente Orellana 1996). In our study this alliance represents communities on sedimentary volcanic soils with fine gravel and clay on hillsides with both xerophytic scrub vegetation between 2700 and 3260 m.
Communities with the columnar cactus *Corryocactus brevistylus* have been described by several authors (Galán de Mera & Vicente Orellana 1996; Galán de Mera & Gómez Carrión 2001; Galán de Mera et al. 2002a, 2003, 2009, 2010, 2011b; Luebert 2004; Galán de Mera 2005). Moreover, the species occurs in mountain regions in South Peru (Mariño et al. 1998; Holmgren et al. 2001; Mauseth et al. 2002, 2006; Medina 2006; NatureServe 2009; Ostolaza 2011, 2014). Popularly known as "sancayo" (Cáceres et al. 2000; Ostolaza 2011), the edible fruits are commonly used by people in the Andes

because of their medicinal properties and vitamin content (Cáceres et al. 2000). Brako & Zarucchi (1993) define its distribution as between 2000 and 3500 m for the southern Peruvian Andes. We found that the species is likely to occur in subhumid scrublands, rarely growing on dry slopes; it was mostly absent from our relevés.
The association *Weberbauerocereo weberbaueri-Corryocactetum brevistyli* (Galán de Mera & Gómez Carrión 2001) has to be rejected as both namegiving cactus species do not co-occur, apart from a small transition zone. The relevés as published by Galán de Mera & Gómez Carrión (2001) were only made in this transition zone. As shown in the synoptic table and supported by the ordination and cluster analysis both species appear to belong to different alliances. The ecology of both cactus species is different; *W. weberbaueri* occurs in xeric ecosystems with very low cover by shrubs, receiving more annual insolation and having sandy soil texture. By contrast, *C. brevistylus* occurs in scrubland ecosystems with higher cover and abundance of shrubs, on sandy to clayey soils in areas that receive higher precipitation because of their proximity to the Prepuna and Puna alpine ecosystems. While the distribution of the Corryocaction is restricted to south and south-western slopes of the Chachani, Misti and Pichu Pichu volcanoes, the relevés of Galán de Mera & Gómez Carrión (2011) have been made in the Yura district between Arequipa city and Chachani volcano.
Also the floristic composition differs considerably. Besides, species in common appear to be only companions. Many of the species described by Galán de Mera & Goméz Carrión (2001) were not found on our sites; they are: *Grindelia boliviana, Bromus villosus, Echinopsis pamparuizii, Opuntia soehrensii, Spergularia congestifolia,* and *Senecio richii*. Except for the two cactae mentioned, these species are likely to occur more in scrubland ecosystems close to the Prepuna and Puna.

7. ***Balbisio weberbaueri-Ambrosietum artemisioidis*** (Table 3, col. 13. Appendix 7. Fig. 8)
Physiognomy and composition: This association consists of scrubland vegetation of semiarid mesotropical bioclimate located on pleistocenic deposits (Galán de Mera et al. 2011b). Columnar cactus, shrubs, herbs and grasses are characteristic of the vegetation with higher density and coverage by *Corryocactus brevistylus*.
Syntaxonomy: Character species are *Bromus trinii, Chersodoma juanisernii, Cumulopuntia mistiensis, Lupinus* cf. *eriocladus, Lupinus saxatilis, Senecio phylloleptus* and *Solanum corneliomulleri.* The perennial endemic shrub *Cantua candelilla,* although found in two relevés only, is restricted to this association. Differential species are *Parietaria debilis, Oxalis megalorrhiza, Tarasa tenuis*.
Ecology and distribution: Growing between 2700 and 3260 m on Pleistocenic sedimentary volcanic soils, in areas where precipitation is probably more abundant than elsewhere in the distribution area of *Weberbauerocereus weberbaueri*. It occurs on the slopes of the Misti, Chachani and Pichu-Pichu volcanoes in the Arequipa province.

The *Balbisio weberbaueri-Ambrosietum artemisioidis* (Galán de Mera et al. 2011b) occurs in our study area and we jointed 37 relevés to describe this association with addition of several character species and a broader overview of its distribution. This unit represents the scrubland cacti communities in South Peru with consistent occurrence of *Corryocactus brevistylus* and the absence of other columnar cacti. This association together with the *Aloysio spathulatae-Corryocactetum brevistyli* represents the units growing on sedimentary volcanic soils at the lower slopes of Misti, Pichu-Pichu and Chachani volcanoes in the Arequipa province and at an elevation of 2800 and 3260 m. Shrub cover is higher in this unit and species abundance comprisses numbers overpassing 60 species.

8. *Aloysio spathulatae-Corryocactetum brevistyli* (Table 3, col. 14. Appendix 8)
Physiognomy and composition: The shrubby vegetation is dense, with high cover of the columnar *Corryocactus brevistylus.* The total cover is more than 80%. Five species of cacti are present. Annuals and grasses are also very common. Eight endemic species are reported for this association.
Syntaxonomy: *Senecio subcandidus, Aloysia spathulata, Senna birostris* var. *arequipensis, Pectocarya anomala* and *Adesmia augusti* are character species. It is further characterized by species with lower constancy like *Austrocylindropuntia subulata Croton ruizianus, Heliotropium toratense, Kageneckia lanceolata, Lantana scabiosiflora* and *Lupinus misticola.*
Ecology and distribution: It grows in the mesotropical belt between 2800 and 3040 m on mostly rocky, sometimes steep slopes with large boulders. It occurs on the lowermost rocky slopes of the Pichu-Pichu volcano in the district of Mollebaya. It differs from the *Balbisio weberbaueri-Ambrosietum artemisioidis* by the sandy-clayey soil texture and higher cover by rocks and stones.

8.1 *oenotheretosum rubidae* (Table 3, col. 14. Appendix 8)
Physiognomy and composition: The vegetation is dense and shrubby.
Syntaxonomy: This subassociation is very well differentiated by many species. Differential species are the tree *Kageneckia lanceolata* (3–5 m), the shrubs *Croton ruizianus* and *Lantana scabiosiflora,* the subshrub *Lupinus misticola*, and besides by species like *Heliotropium toratense, Pectocarya lateriflora, Oenothera rubida, Villanova oppositifolia, Bomarea ovata, Cremolobus chilensis, Gaya mollendoensis, Heterosperma diversifolium, Nama dichotoma, Paronychia microphylla* var. *arequepensis* and *Tigridia arequipensis*[2].
Ecology and distribution: Vegetation of the *oenotheretosum arequipensis* grows at an elevation of 2800 m on rocky slopes (45° inclination) with clayey soil and large boulders in the district of Mollebaya.

2 *Tigridia arequipensis*, a new species from South Peru. Montesinos-Tubée et al. (2016).

8.2 *adesmietosum augusti* (Table 3, col. 14. Appendix 8)

Physiognomy and composition: The vegetation of this subassociation consists mostly of annuals and shrubs.

Syntaxonomy: The *adesmietosum augusti* is differentiated by *Adesmia augusti, Pectocarya anomala, Austrocylindropuntia subulata, Pellaea ternifolia*, *Diplostephium meyenii, Plantago* sp. (# 3327), *Poa asperiflora, Spergularia fasciculata, Pteromonnina macbridei,* and besides by *Junellia arequipense,* the character species of the alliance (with relatively high cover) and *Corryocactus aureus,* diagnostic species of the class and order.

Ecology and distribution: The vegetation of the *adesmietosum augusti* grows on slopes (10°) with abundant rocks and stones at an elevation of 3040 m, in the extensive highland plateaus of Mollebaya and Pocsi districts.

The following eight previously published associations and one subassociation can be assigned to the *Corryocaction brevistyli*. They have been used as reference in the comparison with the syntaxa based on our relevés. Further research is needed to clarify the syntaxonomic position.

Figure 7. Comparison of the arid slopes in Socabaya district (elevation 2320 m), before (A) and after (B) the rain event in which *Cantuo volcanicae-Weberbauerocereetum weberbaueri* occurs.

Figure 8: Rocky slopes represented by the association of *Balbisio weberbaueri-Ambrosietum artemisioidis* in the Chiguata district (3190 m).

Table 3. Table with the presence values of each unit for this study and those from literature. Scientific name (species with one asterisk are indicated as endemics for Peru and species with two asterisk as endemics for the Arequipa province). Presence percentage values (1–100) are given for those communities with more than five relevés and presence values with roman letters are given for those units with less than four relevés. In the *Ambrosio-Weberbauerocerion* the following associations: 1. *Weberbauerocereo weberbaueri-Browningietum candelaris* (this study), 2. *Weberbauerocereo weberbaueri-Browningietum candelaris*, 3. *Senecioni yurensis-Weberbauerocereetum weberbaueri* (this study), 4. *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* (this study), 5. *Lycio distichi-Weberbauerocereetum weberbaueri* (this study), 6. *Cantuo volcanicae-Weberbauerocereetum weberbaueri* (this study) and 7. *Paronychio microphyllae-Weberbauerocereetum weberbaueri* (this study). In the *Neoraimondio arequipensis-Weberbauerocerion rauhii* the following associations: 8. *Weberbauerocereo rauhii-Browningietum candelaris larreetosum divaricatae*, 9. *Armatocereo riomajensis-Neoraimondietum arequipensis*, 10. *Weberbauerocereo rauhii-Browningietum candelaris*, 11. *Weberbauerocereo rauhii-Corryocactetum brevistyli* and 12. *Neoraimondio arequipensis-Browningietum viridis*. In the *Corryocaction brevistyli* the following associations: 13. *Balbisio weberbaueri-Ambrosietum artemisioidis* (this study), 14. *Aloysio spathulatae-Corryocactetum brevistyli* (this study), 15. *Weberbauerocereo weberbaueri-Corryocactetum brevistyli*, 16. *Balbisio weberbaueri-Ambrosietum artemisioidis*, 17. *Corryocacto aurei-Browningietum candelaris*, 18. *Oreocereo tacnaensis-Corryocactetum brevistyli*, 19. *Grindelio bolivianae-Corryocactetum puquiensis*, 20. *Diplostephio tacorensis-Parastrephietum lepidophyllae: corryocactetosum brevistyli*, 21. *Armatocereo riomajensis-Euphorbietum apurimacensis* and 22. *Weberbauerocereo rauhii-Corryocactetum brevistyli crotonetosum ruiziani*.

	Ambrosio artemisioidis-Weberbauerocerion weberbaueri							Neoraimondio-Weberbauerocerion rauhii					Corryocaction brevistyli									
Community number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Relevé #	31	?	39	35	11	19	12	2	2	5	5	9	37	12	7	4	8	2	4	10	7	2
Total species number	66	8	61	68	34	39	35	11	10	18	14	15	76	62	25	20	22	19	36	50	38	16
Characteristics of class and order																						
Opuntia sphaerica	65	II	67	37	36	58	33	I		100	60	44	57	100	86	II	100	II	III	80	43	
Ambrosia artemisioides	52	II	74	94	100	58	100	I	II	100	100	100	30	17	86	IV	86	II			100	
Oreocereus hempelianus	10		41			11		I				27					75	II		20		
Armatocereus riomajensis (**)	16				9				II		100	22									100	II
Haageocereus platinospinus (*)	74				9			I		80	60						50					
Corryocactus aureus (*)				14	9	63	33		I		40	11	5	25			75				29	I
Tarasa operculata	16		85	77	100	84	67						84	67		I				70	86	II
Browningia candelaris	45	II		6				II		100	60						86					
Ambrosio artemisioidis-Weberbauerocerion weberbaueri																						
Weberbauerocereus weberbaueri (*)	35	II	85	89	100	79	100								57							
Exodeconus pusillus	74		41	17	55	26	33															
Neoraimondio arequipensis-Weberbauerocerion rauhii																						
Weberbauerocereus rauhii (*)								II	II	100	100	56										I
Neoraimondia arequipensis	19	II		6				II	II	80		100										
Corryocaction brevistyli																						
Balbisia weberbaueri (*)			5	11	9		33						81	100	29	IV						
Corryocactus brevistylus			12	14							100		100	100	86	IV	86	II	II	100		II
Junellia arequipense (*)													42	50						40	14	
Gochnatia arequipensis				3									27	100		I		II			14	
1. Weberbauerocereo weberbaueri-Browningietum candelaris																						
Calandrinia ciliata	51			11																		
Onoseris odorata (*)	35																					
Euphorbia hinkleyorum	26																					
Nolana spergularoides (**)	26																					
Urocarpidium albiflorum	19				18																	
Haageocereus pluriflorus (*)	16																					
Tarasa sp.1 (# 3559)	16																					
Exodeconus integrifolius	13																					
Tetragonia ovata	13																					
Tiquilia paronychioides	13																					
Exodeconus flavus	10																					
Ozyroe biflora	10																					
Heterosperma ovatifolium	10																					
Astragalus confinis	6																					
Leptoglossis acutiloba (*)	6																					
Plagiobothrys myosotoides	6																					

Community number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Tiquilia grandiflora	6																					
Dalea pennellii	3																					
2. Senecioni yurensis-Weberbauerocereetum weberbaueri																						
Senecio yurensis	23		64	20									8									
Neuontobotrys lanata	23		59										11									
Mostacillastrum pectinifolium (**)			33																			
Chionopappus benthamii (*)			23																			
Oenothera verrucosa (**)			18										11									
Chorizanthe commisuralis			13																			
Cuscuta cockerellii (**)			13										11									
Eremodraba schulzii (**)			13																			
Gaya mollendoensis (**)			13	11										II								
Hoffmannseggia prostrata			13																		14	
Mastigostyla cyrtophylla (*)			13																			
Dipyrena glaberrima			10																			
Cistanthe calycina			8																			
Orobanche weberbaueri (**)			8																			
Tarasa thyrsoidea (*)			8																			
Loxanthocereus jajoianus (**)			3																			
3. Euphorbio apurimacensis-Weberbauerocereetum weberbaueri																						
Euphorbia apurimacensis (*)				83							100										100	
Jatropha macrantha (*)				34								22										
Puya cylindrica (**)				31																		
Astrolepis sinuata	6			26																	29	
Krameria lappacea				23						20	20	11				I					14	
Mentzelia scabra subsp. *chilensis*				14																		
Cheilanthes fractifera (*)				11																		
Stipa plumosa				11																		
Alternanthera halimifolia				9																		
Cheilanthes bonariensis				3																		
Heliotropium arborescens var. *grisellum*				3																		
4. Lycio distichi-Weberbauerocereetum weberbaueri																						
Lycium distichum					64												13					
Aphyllocladus denticulatus					27																	
5. Cantuo volcanicae-Weberbauerocereetum weberbaueri																						
Cantua volcanica (**)						58	I									IV						
Tecoma fulva subsp. *arequipensis*						32								17								
Helogyne apaloidea						5																
Prosopis laevigata var. *andicola*						5																
6. Paronychio microphyllae-Weberbauerocereetum weberbaueri																						
Paronychia microphylla var. *arequepensis* (**)			13	14		32	67						5	25						10		
Dalea exilis					27		83															
Pteromonnina ramosa (**)							75															
7. Balbisio weberbaueri-Ambrosietum artemisioidis																						
Bromus trinii													35									
Lupinus cf. *eriocladus*													28									
Lupinus saxatilis (*)													22									
Chersodoma juanisernii (*)													16									
Cumulopuntia mistiensis (**)													14									
Senecio phylloleptus													14									
Cantua candelilla (**)													5									
Solanum corneliomulleri (*)													5									
8. Aloysio spathulatae-Corryocactetum brevistyli																						
Senecio subcandidus (*)														92							29	
Aloysia spathulata (*)				11										67								
Adesmia augusti (*)														42								
Pectocarya anomala														50								
Senna birostris var. *arequipensis*				3										50								
Kageneckia lanceolata														33								
Croton ruizianus														25		I					14	II
Lantana scabiosiflora				3					I			11		33								
Heliotropium toratense (*)				6										33								
Austrocylindropuntia subulata														25						20	29	II
Lupinus misticola (**)														17								
OTHER CLASS CHARACTERISTICS																						
Nicotiano-Ambrosietea arborescentis																						
Solanum peruvianum	42		49	74	73	5	33						5	17	29					10		
Palauo dissectae-Nolanetea gayanae																						
Cristaria multifida	68		41	3	45	11											63	I				
Tiquilia elongata (*)	19		28																			
Fuertesimalva chilensis	13		38	46	36		92						27	25								
Cryptantha parviflora (*)	10																					
Cistanthe celosioides	29		8												43							
Plantago limensis (*)	32			6	36		25															
Cistanthe paniculata (*)	16		8	6																		
Eragrostis peruviana				17	9	11	75						24	83							14	
Pectocarya lateriflora			79	51		63							68	50								
Bryantiella glutinosa			10																			
Argyrochosmetea niveae																						

Community number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Cheilanthes pruinata	6		15	6			17						57	75					II	20	57	
Cystopteris fragilis	19			17										8								
Pellaea ternifolia	19		31	14	9		42						22	50			13			10	14	
Cheilanthes arequipensis			8	54		5							24									
Myriopteris myriophylla			13	9																		
Woodsia montevidensis													19									
Sedum reniforme (*)			28														25	II			29	
Echinopsio-Proustietea																						
Senecio tovari (*)													16									
Bomarea ovata														25								
Calamagrostietea vicunarum																						
Diplostephium meyenii													24	33	43	I		II	II	70		
Mutisia lanigera													8									
Calceolaria inamoena													3			II						
Olsynium junceum													22									
Lobivia pampana (*)													14									
Polypodio-Tillandsietea																						
Tillandsia capillaris							25															
Deuterocohnio-Puyetea																						
Polyachyrus sphaerocephalus													11							10		
Distichlio-Anthobryetea																						
Suaeda foliosa						11																
Atriplex myriophylla						5																
Atriplex semibaccata						5																
Atriplex rotundifolia (*)			15									11										
Crassuletea connatae																						
Crassula connata			5	3	18								41	8								
Soncho-Bidentetea																						
Mesembryanthemum crystallinum	6																					
Chenopodium petiolare	3		8			32							8						I			
Nicotiana paniculata						21																
Parietaria debilis													54									
Villanova oppositifolia													14	42								
Galinsoga parviflora							33							42								
Companions																						
Aristida adscencionis	81	II	85	66	27	42	67			20			27	75					II		29	
Hoffmannseggia viscosa var. *egena*	10		18	11		16																
Senecio sp. (# 3344)	19		5	14	36																	
Montiopsis cumingii	10		10	60	100								16									
Mirabilis elegans	19		21																			
Oenothera rubida	10						25						16	42								
Oxalis sp. (# 3537)	32				45																	
Plantago linearis			49			37	33						76	33						20		
Drymaria divaricata (*)	23		8	37										66								
Pteromonnina macbridei (**)	6		15										19	42								
Solanum paposanum	6		10	11	73		58						30	17								
Eragrostis nigricans	10			86	45	100	67							58								
Tagetes multiflora	35		77	71	91		100						92	91	14				III	50		II
Portulaca pilosa	19		15	11		21	8							33								
Tarasa rahmerii	16		26	54	18	68							27	75	100				I			
Nama dichotoma	13		62	80	9	11	92						24	25								
Oxalis megalorrhiza			59	51	18								51									
Ephedra americana			26	26	9	26	83	I	I	60	40		43	42	57	I		I	II	40	29	
Mostacillastrum gracile				6		5	92						95	58								
Chenopodium incisum				6		58																
Encelia canescens						53					20				14	II					43	
Allionia incarnata				6		26																
Quinchamalium procumbens							67										63	I		20		
Tigridia arequipensis (**)				6										25								
Senecio vulgaris	3			6		5																
Gamochaeta americana				17									3	25								
Lycianthes lycioides				9										50							14	
Chondrosum simplex						5	33							17							14	
Gamochaeta purpurea							75						22									
Spergularia fasciculata				9			67			20			51	33		I						
Facelis plumosa	3		5	3			8						41	58								
Galium aparine													54	33								
Schkuhria multiflora	6		5	11	27																	
Bowlesia sodiroana	6		21										54	100								
Heterosperma diversifolium	10					47	8							25								
Solanum medians (*)	6		10		18								38									
Viguiera lanceolata				3									8									
Porophyllum ruderale	3																					
Erigeron bonariensis						5							5	17					I			
Malva parviflora						5																
Anredera diffusa				26																		
Fagonia chilensis			10														63					
Trixis cacalioides		II			18					60												I
Grindelia tarapacana													19	17		II						

Community number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Cremolobus chilensis													11	25								
Tarasa tenuis													46									
Descurainia myriophylla													35									
Tarasa rhombifolia (*)													27									
Vulpia myuros													22							10		
Gnaphalium dombeyanum													22							10		
Gnaphalium lacteum													22									
Tarasa sp.2 (# 3689)													14									
Adiantum poiretii													8									
Muehlenbeckia hastulata													5									
Coreopsis fasciculata													5									
Bartsia serrata													5									
Conyza tunariensis													5									
Poa asperiflora													11	25								
Gilia laciniata														17								
Paronychia setigera														8								
OTHER TAXA:																						
Balbisia meyeniana										40	20							II		30		
Larrea divaricata								II														
Atriplex imbricata		I								20												
Tecoma tanaeciifolia										40												
Browningia viridis												100										
Melocactus peruvianus												22										
Proustia berberidifolia															14			I	III	20		I
Echinopsis pamparuizii															14					10		
Tunilla soehrensii															14				IV	20		
Stipa ichu															14	I			I	20	29	
Adesmia spinosissima																I				10		
Muehlenbeckia volcanica																I						
Ophryosporus peruvianus																I			II	10		
Spergularia congestifolia															43		75		I	40		
Atriplex atacamensis																	63	II				
Euphorbia tacnaensis																	25	II		50		
Ligaria cuneifolia																	13					
Parastrephia lepidophylla																		II				
Oreocereus leucotrichus																		II				
Oreocereus tacnaensis																		II		50		
Spergularia collina																		II				
Dunalia spinosa																			II			
Mutisia acuminata																			I	10		
Opuntia exaltata																			III			
Proustia oblongifolia																			II			
Puya ferruginea																			II			II
Tillandsia usneioides																			I		14	
Pitcairnia sp.																			I			
Sedum sp.																			I			
Philibertia solanoides																			I		29	
Alonsoa acutifolia																			I		29	
Calamagrostis humboldtiana																			I			
Nassella asplundii																			I	10		
Caiophora superba																			I			
Artemisa sp.																			I			
Chersodoma jodopappa																			II			
Senecio richii															29				I	10		
Corryocactus puquiensis																			IV		71	
Grindelia boliviana															29				IV	30		
Argyrochosma nivea																	13		I	10		I
Franseria fruticosa																				90		
Fabiana stephani																				50		
Baccharis boliviensis																				20		
Bromus lanatus																				20		
Calamagrostis intermedia																				20		
Belloa piptolepis																				10		
Calamagrostis vicunarum																				10		
Chersodoma arequipensis																		I		10		
Euphorbia sp.																				10		
Junellia juniperina																				10		
Muhlenbergia peruviana															14					10		
Nassella pubiflora																				10		
Senecio clivicolus																				10		
Tetraglochin cristatum																				10		
Viguiera procumbens																				10		
Grindelia bergii																					14	
Baccharis uniflora																					14	
Dalea cylindrica																					57	
Opuntia tunicata																					43	II
Carica augusti																						II
Opuntia ficus-indica																						I
Zinnia peruviana																						I

- Table 3, comm. 15: *Weberbauerocereo weberbaueri-Corryocactetum brevistyli* Galán de Mera & Gómez Carrión 2011
- Table 3, comm. 16. *Balbisio weberbaueri-Ambrosietum artemisioidis* Galán de Mera et al. 2011
- Table 3, comm. 17: *Corryocacto aurei-Browningietum candelaris* Galán de Mera & Vicente Orellana 1996
- Table 3, comm. 18: *Oreocereo tacnaensis-Corryocactetum brevistyli* Galán de Mera & Vicente Orellana 1996
- Table 3, comm. 19: *Grindelio bolivianae-Corryocactetum puquiensis* Galán de Mera & Gómez Carrión 2001
- Table 3, comm. 20: *Diplostephio tacorensis-Parastrephietum lepidophyllae corryocactetosum brevistyli* Galán de Mera et al. 2003
- Table 3, comm. 21: *Armatocereo riomajensis-Euphorbietum apurimacensis* Galán de Mera et al. 2009
- Table 3, comm. 22: *Weberbauerocereo rauhii-Corryocactetum brevistyli crotonetosum ruiziani* Galán de Mera et al. 2009

Overview of the xerophyte plant communities after extreme rainfall

Dillon & Rundel (1989) and Thibault & Brown (2008) have demonstrated how extreme precipitation events greatly modify the structure and composition of arid and semi-arid vegetation, noting that it is predicted that due to climate change and ENSO events these variations may occur. It is noteworthy that these events are still poorly known in terms of their effects on the xerophytic vegetation of Peru. It can be deduced that they can greatly modify the structure of a plant community generating lush cover and frequency of annuals not seen in normal years of precipitation. Nevertheless it has been observed that biannuals and perennials are also affected, but not as much as the annual vegetation in terms of cover and abundance.

In the arid ecosystems studied, we found that all vegetation along a 1000-m elevation transect changed more in structure (species cover and abundance) than in species composition (species presence or absence). As the relevés were made 75 days after the start of the rainy season, we were able to sample the vast majority of annuals. Plant communities in the xerophytic ecosystems changed dramatically (Fig. 7a–b) in physiognomy and composition after the high rainfall event in comparison to normal years of precipitation. On the arid slopes of Chapi (Polobaya district), 6 of the 52 species are perennial (cacti, 11.5%) and the remaining 46 (88.5%) are annuals that germinated after the exceptional heavy rainfall. In the scrubland cacti association of *Balbisio weberbaueri-Ambrosietum artemisioidis*, 21 (32.2%) of the 78 species are biannual to perennial and the remainder (67.7%) is annual.

Vegetation in arid areas is primarily limited by precipitation. The *Ambrosio artemisiodis-Weberbauerocerion weberbaueri* communities are no exception. According to the hypothesis

of Holmgren et al. (2001), plant communities change rapidly along steep elevation-precipitation gradients. We describe different associations with *Weberbauerocereus weberbaueri* occurring in areas with irregular limited annual precipitation, sometimes only 120 mm/year. In this climate, above 3000 m, on the hills and slopes of Misti, Chachani, and Pichu-Pichu volcanoes, woody species are abundant in association to *Corryocactus brevistylus* and the plant communities apparently did not change greatly after the extreme rainfall of 2012.
In the *Weberbauerocereus weberbaueri* communities on dry slopes, we found that plant cover and diversity of annual species changed dramatically after the extreme rainfall of 2012. This temporary event favored species that are not found in dry years.

Plant community composition and distribution

The only tree reported in our study area is a woody legume (*Prosopis laevigata* var. *andicola*) associated among other species, with *Tecoma fulva* subsp. *arequipensis* and *Weberbauerocereus weberbaueri,* as can be seen in the Yarabamba extensive plains and slopes. From the photograph published by Weberbauer (1945) (Fig. 10), we deduce that these communities used to be well represented on the hills where Arequipa city now lies. Furthermore, these plant communities can still be found in the surroundings

Figure 9. Xeric environs of Arequipa city showing the scattered distribution of the columnar *Weberbauerocereus weberbaueri i*n a vegetation dominated by dwarf shrubs (most probably *Ambrosia artemisioides* and *Tarasa operculata*). Photograph by Walter V. Runcie, taken in 1939 between Cayma and Cerro Colorado district (Weberbauer 1945: 309). In present time the city of Arequipa is here established.

of the Alfredo Rodriguez Ballon Airport (district of Cerro Colorado) and in the hills of Yarabamba and Mollebaya district.

On the other hand, the community of *Atriplex rotundifolia* and *Ephedra americana* (Galán de Mera et al. 2011b) occurs in the lomas formations. Both species are widely distributed between 500 and 3000 m in the department of Arequipa (Brako & Zarucchi 1993). *Ephedra americana* is also present between 3400–3700 m in the Prepuna of Moquegua (Montesinos et al. 2012). Therefore *E. americana* can be considered a companion species for different phytosociological units in South Peru.

Introduced species like *Aristida adscensionis, Galium aparine, Mesembryanthemum crystallinum, Malva parviflora, Senecio vulgaris, Vulpia myuros* can be found over a wide range of ecosystems in the Arequipa province, especially in urban areas, on agricultural land, and in grazed areas. They are increasingly becoming an environmental problem for natural communities (especially those close to urban areas), where many native and endemic species can be outcompeted by the alien species. It is well known that introduced species may outcompete native species and change the structure and functioning of native communities and ecosystems (Bossdorf et al. 2005). Generally urbanization leads to an increase of grasses and herbs at the cost of woody species (Marzluff & Ewing 2001, McKinney 2008). This has a negative effect on the diversity of birds and other animals, which is correlated with vegetation structure and plant species richness (McKinney 2008). This may become a serious problem for the conservation of native and endemic species in the near future, aggravated by expanding urbanization without concern for the degradation of natural communities. Nature conservation should be prioritized here.

In the synoptic table (Table 3), many species that have been used for vegetation classification in our study, belong to other classes and are hence companion species in the syntaxa described. Other classes are compared as follows:

The *Nicotiano-Ambrosietea arborescentis* (Galán de Mera et al. 2002a) includes *Solanum peruvianum,* a nitrophytic plant well represented in coastal and scrubland ecosystems of Peru as shown in Tropicos database (http://www.tropicos.org) and Brako & Zarucchi (1993). It is a common in the vicinity of the *Ambrosio artemisiodis-Weberbauerocerion weberbauer*i and is considered an annual or biannual species. On the other hand, the *Palauo dissectae-Nolanetea gayanae* (Galán de Mera 2005) represents Peruvian Pacific coastal communities. Several of the mentioned species are also found on the arid slopes above 2000 m, for example *Cistanthe celosioides, C. paniculata, Cristaria multifida, Cryptantha parviflora, C. peruviana, Eragrostis peruviana, Fuertesimalva chilensis, Bryantiella glutinosa, Pteromonnina ramosa, Pectocarya lateriflora, Plantago limensis* and *Tiquilia elongata*. We found most of these species occurring on sandy slopes of the Arequipa province. They emerged after the severe rainfall of 2012. Regarding to the chasmophyte vegetation, we considered the *Argyrochosmetea niveae* (Gutte 1986) where several ferns and some succulents are characteristic of rock edges and fissures. We found that *Cheilanthes arequipensis, C. myriophylla, C. pruinata, Cystopteris fragilis, Pellaea* *ternifolia, Sedum reniforme* and *Woodsia montevidensis* occur on semi arid and scrubland slopes, mostly within the *Weberbauerocerion weberbaueri* and the *Corryocaction brevistyli*. The occurrence of these species is occasional and they form part of the companions in the xerophyte communities. For instance, also the halophyte class *Distichlio-Anthobryetea* (Navarro 1993) is present where *Atriplex myriophylla, A. rotundifolia, A. semibaccata* and *Suaeda foliosa* are reported in one association (*Weberbauerocereo weberbaueri-Tecometum arequipensi*), which is near the salt marshes in the Socabaya district, where the *Batido-Salicornietea ambiguae* Borhidi 1996 (Montesinos-Tubée 2012b) occurs. The scrubland class *Echinopsio-Proustietea* (Montesinos et al. 2012) and the grassland class *Calamagrostietea vicunarum* (Rivas-Martínez & Tovar 1982) contain some species also present in the scrubland units close to the puna. The species *Diplostephium meyenii, Lobivia pampana, Calceolaria inamoena, Senecio tovari,* among others, are occassionally present in the *Corryocaction brevistyli*. The *Soncho-Bidentetea* Hoff 1983 (Galán de Mera 2005) comprises ruderal species that are close to urban and agricultural areas, we have distinguished few species of this class such as *Chenopodium petiolare, Galinsoga parviflora, Mesembryanthemum crystallinum, Nicotiana paniculata, Parietaria debilis* and *Villanova oppositifolia* occurring in our study area. These species may indicate the anthropic activities near the communities. Inside the *Polypodio-Tillandsietea* Bolòs, Cervi & Hatschbach 1991 (Galán de Mera 2005), we include *Tillandsia capillaris,* an epiphyte plant growing occasionally on *Balbisia weberbaueri* stems. Finally, in *Deuterocohnio longipetalae-Puyetea ferrugineae* Rivas-Martínez & Navarro in Navarro & Maldonado 2002 (Galán de Mera 2005), we include *Polyachyrus sphaerocephalus,* a perennial climber with pink flowers, which grows in rock crevices as seen in the *Balbisio weberbaueri-Ambrosietum artemisioidis*.

Cluster analysis and DCA ordination

After construction of a dendrogram (not shown) with all clusters and communities, a group with very low similarity to our syntaxa appeared as outgroup. The outgroup comprises the following previously published syntaxa: *Grindelio bolivianae-Corryocactetum puquiensis* Galán de Mera & Gómez Carrión 2001, *Haageocereo limensis-Neoraimondietum arequipensis* Galán de Mera & Rosa 2002, *Tristerido peruviani-Myrcianthetum quinquelobae* Galán de Mera & Rosa 2012, *Barnadesio blakeanae-Ophryosporidetum peruviani* Galán de Mera & Cáceres 2002, *Adiantetum subvolubilis* Galán de Mera & Rosa 2002, *Neoporterio islayensis-Neoraimondietum arequipensis* Galán de Mera et al. 2002, *Acantholippio deserticolae-Atriplicetum imbricatae atriplicetosum imbricatae, ambrosietosum artemisioidis* Luebert & Gajardo 2005, *Weberbauerocereo torataensis-Corryocactetum brevistyli* Galán de Mera et al. 2009, *Schino mollis-Tecometum arequipensis* Galán de Mera et al. 2009, *Schino mollis-Tecometum tanaeciiflorae* Galán de Mera et al. 2009, *Acacio macracanthae-Tecometum guarumis* Galán de Mera et al. 2009, Community of *Prosopis pallida, Tecometum fulvae* Galán de Mera et al. 2009, *Echinopsio* *chalaensis-Randietum armatae* Galán de Mera et al. 2009, *Polyachyro sphaerocephali-Puyetum densiflorae* Galán de Mera et al. 2009, *Dunalio spinosae-Baccharidetum latifoliae* Galán de Mera et al. 2003, *Lycio distichum-Baccharidetum uniflorae* Galán de Mera et al. 2011, *Anredero diffusae-Diplostephietum meyenii* Montesinos, Cleef & Sýkora 2012. The outgroup was removed from the data set and a new dendrogram (Fig. 11) was constructed. Already at a low similarity level 3 clearly distinct groups appeared corresponding with the three alliances delineated in the syntaxonomic table (Table 3). Communities 1 to 7 in the dendrogram represent the *Ambrosio artemisiodis-Weberbauerocerion weberbaueri*, communities 8 to 12 the alliance *Neoraimondio-Weberbauerocerion* and communities 13 to 22 the *Corryocaction brevistyli*.

Also in the DCA diagram (Fig. 11) the three alliances occurred as three distinct non-overlapping units, confirming the results of the cluster analysis. Although community 17 was overlapping while displaying axes 1 and 2, this is not the case with DCA axes 1 and 3 (not shown). The alliances are ordered along the main floristic gradient from left to right as follows: *Neoraimondio-Weberbauerocerion*, *Ambrosio artemisiodis-Weberbauerocerion weberbaueri* and *Corryocaction brevistyli*. This gradient corresponded with a moisture gradient from dry climate with very little precipitation to a more subhumid climate. The second axis corresponded to an increase in elevation.
The distinction of the three alliances is confirmed by the dendrogram and the DCA diagram. Although in the final analysis we only used a dataset in which the annuals were deleted and only perennials, excluding those with very low occurrence were used, we besides conducted a series of tests using different sets of species and all resulted in a division of two separate units characterized by these columnar cactae previously mentioned to be diagnostic species of one sole alliance (*Corryocaction brevistyli*). The separation of *Weberbauerocereus weberbaueri* and *Corryocactus brevistylus* as character species of two separate alliances is not only confirmed by the statistical analysis, but also agrees with the distribution and ecological conditions of these columnar cactus species along the interandean dry valleys.

Endemism

The area is supported by species that are localy, or widely distributed within the study region. A total of 50 endemic species were found in the studied sites of the Arequipa province corresponding to 27% of the total flora. In Fig. 12, the total number of endemics is shown for each of the eight associations described in this study. From the total number of endemics, 18 species (9.6%) are endemic to the Arequipa region (Brako & Zarucchi 1993, León et al. 2006, http://www.tropicos.org). The two associations with highest number of endemics are *Senecioni yurensis-Weberbauerocereetum weberbaueri* (Yura district) with, 11 species endemic to Peru and nine species to the Arequipa province and the *Balbisio weberbaueri-Ambrosietum artemisioides* (10 species endemic to Peru and six endemics to the Arequipa region) from the Misti volcano slopes.

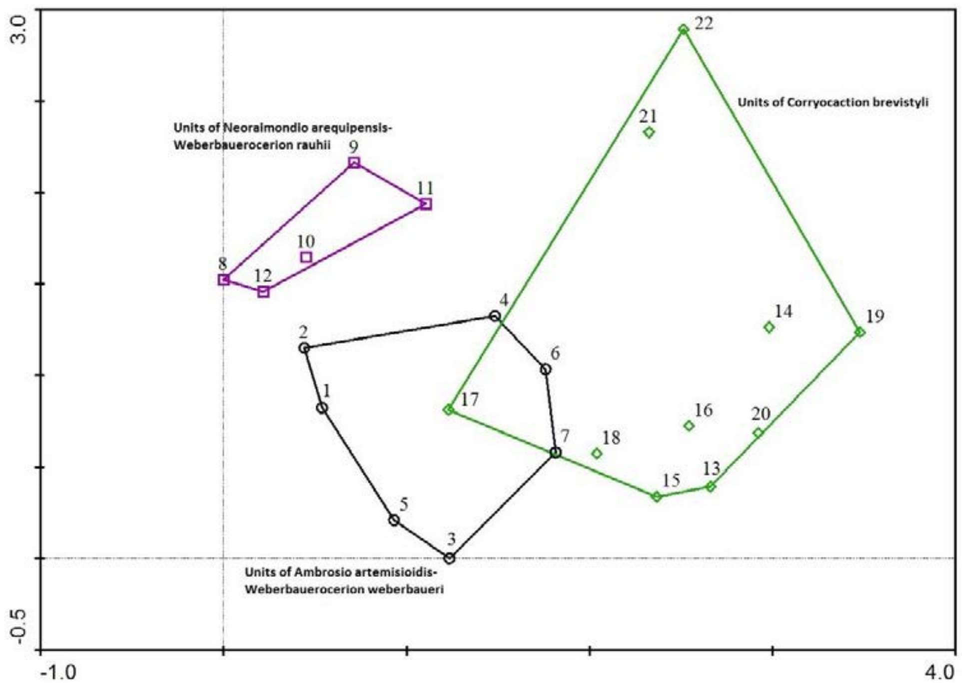

Figure 10. First axis DCA analysis of 22 vegetation units (weighed by presence class) and based on 55 plant species (see Methods and Table 3 for the vegetation units in the synoptic table). The points representing the respective alliances are enveloped. Axis 1 eigenvalues (0.526) and length of the gradient (3.257) and Axis 2 eigenvalues (0.330) and length of the gradient (2.995).

In some associations the character species are mainly or even only represented by species with relatively low presence class. This can be explained by the scattered and distant occurrence of these species although characteristic of the representative and homogeneous vegetation.

Comparison with other xeric vegetation units outside Peru

As stated in the introduction, the xerophytic plant formations have been studied in South America by Sarmiento (1975). Later studies have broadened the knowledge of how plant communities are distributed along the arid regions of the Pacific coast and on dry inter-Andean slopes. Outside of Peru, several authors have studied plant communities and formations with xerophytic species. In Ecuador, Loayza & Morrone (2011) described the distribution of cacti stating that few species have an ample distribution range deducing that plant community description to association level is yet unknown in different regions of the country. In Chile, Villagrán et al. (1981, 1982), Gutiérrez et al. (1998), Luebert & Gajardo (2000, 2005), Navarro & Rivas-Martínez (2005) and Luebert & Pliscoff (2006) present overviews of the vegetation of the arid scrubland and grassland formations. Luebert & Gajardo (2005) described the *Acantholippio deserticolae-Atriplicetum imbricatae* Luebert & Gajardo which has been included in the *Opuntietea sphaericae*, but this association does not share any species with our study except *Ambrosia artemisioides*. Other

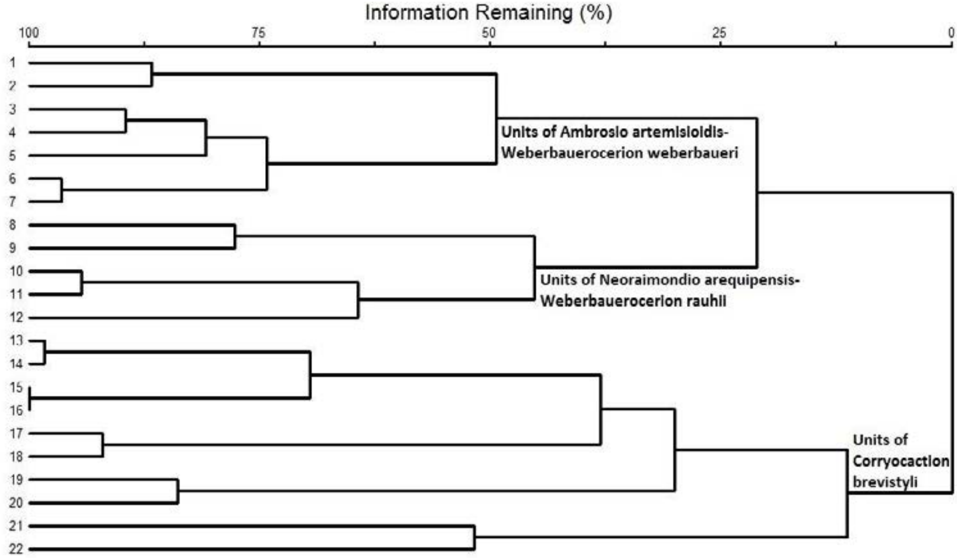

Figure 11. Bray-Curtis distance measure dendrogram with Farthest Neighbor linkage method. The analysis produced 22 clusters (weighed by presence class) and based on 55 plant species (see methods and Table 3 for the synoptic table). For the names of the communities presented in the dendrogram we refer to Table 3.

xerophytic species included Chilean endemics and were absent in our sites. In Bolivia, Navarro (1996) and Navarro & Maldonado (2002) described the occurrence of xerophytic species in different ecosystems, also at the phytosociological level but their units differ greatly and do not resemble those of South Peru.

Since the late 1950s, the slopes of the Chili and Sabandía rivers, San Lázaro and adjacent ravines, have been increasingly populated without supervision or control. This trend generated a great loss of biodiversity. Until today no conservation program exists. Nevertheless, some organizations have made strenuous efforts to improve the conservation of the dry ecosystems of the Arequipa province by mass forestation with native and introduced trees in order to counteract air pollution (Montesinos-Tubée 2012c) and by the creation of local botanical gardens. Other issues concern desertification which also causes the degradation of ecosystems. Major disturbances are related to volcanism, seismic activity and flashfloods. The city of Arequipa is located in one of the most active volcanic chains of the Andes where Misti volcano is considered a serious threat (Sandri et al. 2014). Earthquakes are also frequent in the Arequipa region (Tavera et al. 2002); they may cause severe damage and rock avalanches on nearby mountain slopes. Although these natural disturbances can cause losses to certain ecosystems at the same time they can create new natural habitats and restart succession.

The local governments must urgently address the long-term conservation of the slopes near the Arequipa city, since the fragile arid ecosystems have a significant seed bank with

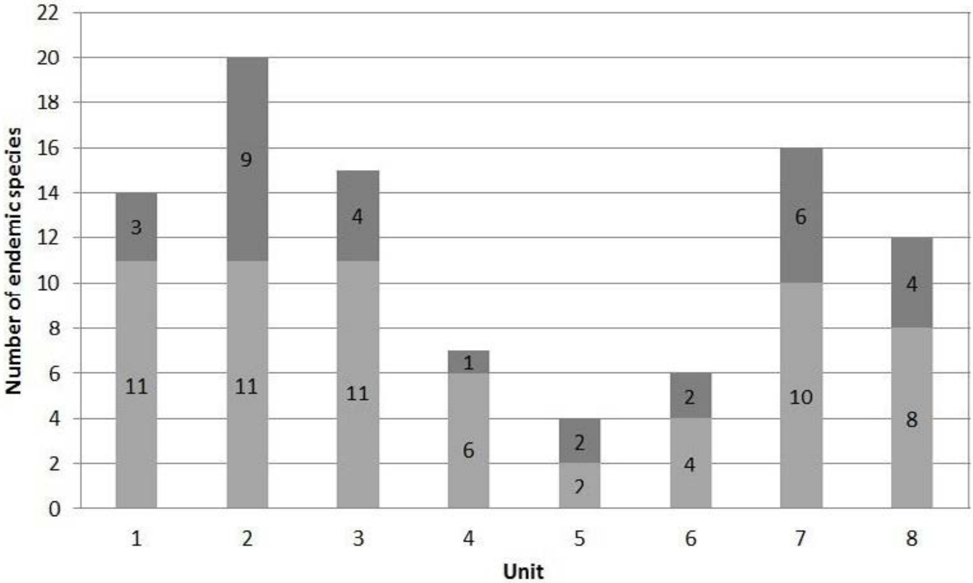

Figure 12. Diagram indicating the total number of endemic species found in the associations described in this publication. Light grey columns indicated for number of endemic species from Peru and dark grey columns for the number of endemic species proper to the Arequipa region. Were: 1.***Weberbauerocereo weberbaueri-Browningietum candelaris***, 2. ***Senecioni yurensis-Weberbauerocereetum weberbaueri***, 3. ***Euphorbio apurimacensis-Weberbauerocereetum weberbaueri***, 4. ***Lycio distichi-Weberbauerocereetum weberbaueri***, 5. ***Cantuo volcanicae-Weberbauerocereetum weberbaueri***, 6. ***Paronychio microphyllae-Weberbauerocereetum weberbaueri***, 7. ***Balbisio weberbaueri-Ambrosietum artemisioidis*** and 8. ***Aloysio spathulatae-Corryocactetum brevistyli***.

high diversity and richness in endemics (25.5%). Nature conservation and urbanization supervision and control must be addressed to avoid the loss of diversity in the Arequipa environs.

Final conclusions

For full comprehensive comparison based on all life forms it is recommendable to make many more relevés of other habitats and regions including all life forms. It is obvious that more research is needed before an overall revision of the succulent rich vegetation of the Peruvian Andes is possible. Many previously described associations, when confronted in an overview based on a synoptic table, are missing diagnostic species. As this appears to be a huge and complicated task, it is highly advisable to perform this project in a joint effort with all vegetation experts of the region.

APPENDIX 1. PAGE 53

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Area (m2)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Altitude (m) x 10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	0	0	0	0	0	0	0	0	0	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	1	0	0	0	
	3	3	3	2	2	2	2	2	2	0	0	0	8	8	8	8	7	7	7	7	7	7	7	7	3	9	9	0	3	3	2	
Slope (°)	45	45	45	40	45	40	35	40	35	45	45	45	12	12	12	12	25	30	30	30	30	25	25	25	45	50	50	15	45	45	40	
Aspect	S	S	S	S	S	S	S	S	S	S	S	S	NNW	NNW	NNW	NNW	ENE	S	S	S	S	ENE	ENE	ENE	S	SSW	SSW	NNE	S	S	S	
Species #	13	12	9	11	11	11	12	12	9	26	17	23	19	27	25	20	17	18	8	13	10	10	9	13	11	9	11	15	10	11	10	
																																PC
Character species of class and order																																
Haageocereus platinospinus	5	5	4	4	4	5	5	6	6	4	4	4		2	2		4	4		2		5	4	3	2					2	2	74
Opuntia sphaerica	2	2	3			2	3						4	4	4	3	4	4		2	3			4	2	2	3	2	3		2	65
Ambrosia artemisioides	2		2	3	3		3	3		3				3	3		3			2					2		3		2	3	3	52
Armatocereus riomajensis														4		5		5				6	5									16
Tarasa operculata	2												1					2	1		2											16
Oreocereus hempelianus													2		4	2																10
Ambrosio artemisioidis-Weberbauerocerion weberbaueri																																
Weberbauerocereus weberbaueri		3						4						2									4		4	5	5	4	3	3	2	35
Exodeconus pusillus	1		1	1	1	1	1	1	1	1	1	1	1	1	1	2	2					1	2	1			2		1	1	1	74
Weberbauerocereo weberbaueri-Browningietum candelaris																																
Browningia candelaris					4	5		4		5	5	5	4	5	5	4									4	5	5			3		45
Calandrinia ciliata	2		1	1		1	1		1						1		1	1		1					1	2	1	2	1	1		51
haageocereetosum plurifoli																																
Haageocereus pluriflorus		1		2		1	2		1																							16
Nolana spergularoides	1		1	1	1	1	1	1	1																							26
onoseridetosum odoratae																																
Onoseris odorata										1	1		1	1		1		2	2	1	2	1		1								35
Tagetes multiflora										2	1	1	1	1	1	1	2	1		1				1								35
Oxalis sp. (# 3537)										2	2	2	1	2	2		2	2	1	2												32
Plantago limensis										1	1	2	1	2	1	1	1	1			1											32
Euphorbia hinkleyorum													2	3	3	3		2	2	2	2											26
Drymaria divaricata										1							1	1	1		1	1		1								23
Senecio yurensis		2								4	4	2	1	2	2																	23
Cystopteris fragilis										2	1	1			1			1			1											19
Mirabilis elegans										3			3	3	4		3	2														19
Pellaea ternifolia										1		1		1	1			1		1												19
Portulaca pilosa												1	2	2			1					1		1								19
Urocarpidium albiflorum										1		1			1		1			1			1									19
Tarasa sp.1 (# 3559)										2	2	2		2	1																	16
Tarasa rahmerii										1		1					1					1	1									16
Exodeconus integrifolius										2	2	2		1																		13
Fuertesimalva chilensis										2		1	2			1																13
Heterosperma ovatifolium												1		1	1																	10
Oenothera rubida										1	1	1																				10
Ozyroe biflora											1		1			1																10
Astragalus confinis													1		1																	6
Plagiobothrys myosotoides														1		1																6
neoraimondietosum arequipensis																																
Neoraimondia arequipensis																									3	3		5	4	4	5	19
Tiquilia paronychioides																										1			1	1	1	13
Tetragonia ovata																									1		1		1	1		13
Exodeconus flavus																										2	1	1				10
Leptoglossis acutiloba																									1			1				6
Tiquilia grandiflora																											1	1				6
Companions																																
Aristida adscencionis	3	2	1	1	2	1	1	1	1				2	2	2	2	3	2	2	3	2	4	4	4	1			4	1	1		81
Cristaria multifida		1	1	1		1	1		1	1	1	1	1	1	1	2	2	2	1	2	1	2	2	2								68
Solanum peruvianum		1		2		1		1	2		1		2	1		2			2		1		1	2								42
Cistanthe celosioides	1	1			1			2																	1	1	1	2			1	29
Neuontobotrys lanata	2				2			2		2		2														2			2			23
Senecio sp. (# 3344)						1			1									1						1				1			1	19
Tiquilia elongata		2		2			2																				2	2			1	19
Cistanthe paniculata		1		1			1							1		1																16
Nama dichotoma					1			2						1	1																	13
Cryptantha parviflora			1		1			2																				1		1		10
Eragrostis nigricans																	1			1		4										10
Heterosperma diversifolium												1		1	1																	10
Hoffmannseggia viscosa var. *egena*										1		1																1				10
Montiopsis cumingii														1	1	1																10
Astrolepis sinuata	1									1																						6
Bowlesia sodiroana							1									1																6
Cheilanthes pruinata	1									1																						6
Mesembryanthemum crystallinum	1	1																														6
Pteromonnina macbridei					1									1																		6
Schkuhria multiflora																	1	1														6
Solanum medians										2		1																				6
Solanum paposanum											3					2																6

Sites: 1–9 Variante de Uchumayo, Uchumayo district; 10–24: Arid slopes in Chapi (Polobaya district); 25–31 El Huayco, Uchumayo district.
Other species: *Facelis plumosa* 1 in 12; *Dalea pennellii* 3 in 21; *Porophyllum ruderale* 1 in 24; *Chenopodium petiolare* 1, *Senecio vulgaris* 1 in 28.

Appendix 1. *Weberbauerocereo weberbaueri-Browningietum candelaris* and subassociations

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
Area (m2)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Altitude (m) x 10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	6	6	6	9	7	7	7	7	7	6	6	6	6	7	7	7	7	7	7	7	6	6	6	6	6	6	4	4	4	4	4	4	4	4	5	5	5	5	5	
	6	6	6	0	3	3	3	3	3	1	1	1	1	0	0	0	0	0	0	0	7	7	7	7	7	7	5	5	5	5	5	5	5	5	9	9	9	9	9	
Slope (°)	7	7	7	34	25	25	25	25	25	60	60	60	60	6	6	6	6	6	6	6	40	40	40	40	40	40	20	20	20	20	20	20	20	20	10	10	10	10	10	
Aspect	NW	NW	NW	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	WS	WS	WS	WS	WS	WS	E	E	E	E	E	E	E	E	N	N	N	N	N	
Species #	15	16	14	18	15	16	12	17	11	16	18	18	17	16	19	19	18	20	18	19	23	23	22	23	26	23	13	14	14	12	15	19	14	16	9	11	11	9	8	
																																								PC
Character species of class and order																																								
Tarasa operculata	4	4	3	3	4	3	2	3	1					4	4	4	3	4	4	4	4	3	1	3	2	3	1	2	2		1	1		2	1	1	1	2	2	85
Ambrosia artemisioides				3	4	2		2	2	5	4	5	4	3	3	2	3	4	3	3	3		3	3	2		3	2		3	2	2	3	2		3	3			74
Opuntia sphaerica	2	3	2							2	2	2	2	5	2	4	4	4	4	4	4	4	3	4	3	3		2	2	2		2	2	1						67
Oreocereus hempelianus	4	5	5	4		3		3	4	5	4	5	5			3		3				3	3													3				41
Corryocactus brevistylus																					5	5	4	5																12
Ambrosio artemisioidis-Weberbauerocerion weberbaueri																																								
Weberbauerocereus weberbaueri	5	5	5	5	6	5	5	5	5	2		5		7	6	6	6	6	6	6	5	5	5	5	5	5	5	4	4	4	4	4	4	4					4	85
Exodeconus pusillus	1	2	2																								5	4	4	4	4	5	3	4	2	3	2	2	2	41
Senecioni yurensis-Weberbauerocereetum weberbaueri																																								
Senecio yurensis					1						1		2	1	1	1	2	2	1	1	2	2	2	2	3	2	2	3		2	2	3		3	2	2	2			64
Neuontobotrys lanata	1	1	2			2				3	2	3	2	3	1	2	1	2	3	2	2	2	2	3	2	2										2	2			59
Mostacillastrum pectinifolium		1		1	2		2	1				1		1			1		1			1		1	2	1														33
oenotheretosum verrucosae																																								
Oenothera verrucosa	1	1		1		2	1	1	1																															18
Atriplex rotundifolia				4	2		3	4			2		2																											15
Cuscuta cockelerii				2	2	1		2	1																															13
Cistanthe calycina										1		2	1																											8
Loxanthocereus jajoianus											2																													3
chionopappetosum benthamii																																								
Tarasa rahmerii														1	2	2	1	1	2	2	1			1	1															26
Chionopappus benthamii												4			6	6	6	5	6	5		2		4																23
Bowlesia sodiroana															1	1		1	1	1		1	1			1														21
Cheilanthes pruinata																					1	1	1	1	1	1														15
Gaya mollendoensis																						1	1	1	1	1														13
Myriopteris myriophylla															2	2		1	2	2																				13
Dipyrena glaberrima														3			3				3					3														10
Solanum medians																					1	2	2		1															10
Cheilanthes arequipensis																					1			1	2															8
ephedretosum americanae																																								
Ephedra americana																								2	2		5	5	5	5	4	5	5	4						26
Mirabilis elegans																											2	2	1	2	2	2	2	2						21
Hoffmannseggia prostrata																													1	2		1	1	1						13
Mastigostyla cyrtophylla																											1		1		1	1		1						13
Bryantiella glutinosa																											1					1	1	1						10
Montiopsis cumingii																												2	2		2			2						10
Cistanthe celosioides																												1			1		1							8
Tarasa thyrsoidea																												1		1			2							8
eremodrabetosum schulzii																																								
Eremodraba schulzii																																			5	5	5	5	4	13
Chorizanthe commisuralis																																			1	1	1	1	1	13
Orobanche weberbaueri																																			1		1	1		8
Companions																																								
Aristida adscencionis	1	1	1	1	1	2	2	2	1	1	1	2	1	1	1	1	1	1	1	1		2	1	2	1	1	2	2	3	3	2	4	2	2						85
Pectocarya lateriflora	1	1	2	1	1	1	1	1	1	1	1	2	1	2	2	1	2	2	3	2	1	1	2	1	2	2		2	1		2	2	2							79
Tagetes multiflora	3	2	1	3	2	2	2	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1									1	1	1	1		77
Nama dichotoma	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1														62
Oxalis megalorrhiza	2	1	2	1	1	1	2	1		2	2	1	2	2	2	2	2	2	1	2	1	2																1	2	59
Plantago linearis	1	2	1	2	2	2	3	1	2	1	2	1	1								1	1	1	1	1	1														49
Solanum peruvianum														2	1	2	2	1	2	2	2	1	2	2	2	2	1	1	1		1	1		1						49
Cristaria multifida	1	1	1																								2	1	2	1	2	1	1	1	2	2	3	2	2	41
Fuertesimalva chilensis				2				2						2	2	2	1	1	2	1	1	2	3	2	3	2														38
Pellaea ternifolia											2	1	1		2	1		2		1		2	1	1	2	2														31
Sedum reniforme					2					2	2	1	2								2	2	2	3	3	2														28
Tiquilia elongata																											1		1	1	1	2		1	4	4	4	4	5	28
Hoffmannseggia viscosa var. *eger*	1	1	1												1		1	1		1																				18
Pteromonnina macbridei				1	1	1	1	1	1																															15
Portulaca pilosa										2	2																		1			1	1	1						15
Paronychia microphylla var. *arequepensis*										3	2	2	2								2																			13
Cistanthe paniculata																							1		1		1			1										10
Fagonia chilensis										2	1	2	2																											10
Solanum paposanum				2	2	1	1																																	10
Chenopodium petiolare				2		1		2																																8
Drymaria divaricata																					1				1	1														8
Balbisia weberbaueri																									2	2														5
Crassula connata																									1	1														5
Facelis plumosa																					1					1														5
Schkuhria multiflora																															1	1								5
Senecio sp. (# 3344)																																1	1							5

Sites: 1–6, 13–26 Corontorio, Yura district; 7–12 Cerro Los Andes - Cono Norte, Yura district; 27–34 Quebrada Enlozada, Congata, Uchumayo district; 35–39 Corontorio, Yura district.

Appendix 2. *Senecioni yurensis-Weberbauerocereetum weberbaueri*

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
Area (m2)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Altitude (m) x 10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	7	7	7	6	6	6	6	5	5	5	5	4	4	4	4	4	5	5	5	5	4	4	4	4	4	3	3	3	3	3	4	3	3	3	3	
	4	4	4	8	5	4	2	6	6	6	6	6	6	6	6	6	8	6	4	2	8	6	4	2	0	8	6	4	2	0	6	4	4	4	4	
Slope (°)	5	5	5	40	40	40	40	40	40	40	40	40	40	40	40	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	40	38	38	38	38	
Aspect	N	N	N	N	N	N	N	E	E	E	E	NN	NN	NN	NN	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	NN	E	E	E	E	
Species #	21	20	16	20	20	21	18	17	19	15	21	21	19	20	15	18	18	14	11	15	12	15	14	14	14	14	7	16	13	12	18	17	19	22	24	
																																				PC
Character species of class and order																																				
Ambrosia artemisioides	4	5	4	5	5	5	5		6		5	5	5	5	5	3	5	4	6	6	6	5	6	5	4	4	6	5	5	5	5	4	6	4	5	94
Tarasa operculata	3	2	3	5	2	4		4	3	2	4	2	4	3	4	2	2			1			2	4	2	2			3	3	5	4	4		4	77
Opuntia sphaerica		2		2			2	2				2					3					2								2	3	2	2	3	2	37
Corryocactus aureus							4									2						2											3		3	14
Corryocactus brevistylus	4	4		5														5						4												14
Browningia candelaris																				5						4										6
Neoraimondia arequipensis																													4	5						6
Ambrosio artemisioidis-Weberbauerocerion weberbaueri																																				
Weberbauerocereus weberbaueri	5	4	5		5	5	5	4	5	6	5	5	5	5	6	4	4		3		5	5		4	5	5	5	5	4	4	6	6	6	6	6	89
Exodeconus pusillus																1	1	2		1	1			1												17
Euphorbio apurimacensis-Weberbauerocereetum weberbaueri																																				
Euphorbia apurimacensis	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	2	5	5	4	4	4		5				2			5	5	5	5	5	83
Puya cylindrica					5	5				5	5	5	5	5	5	4						4													5	31
kramerietosum lappacea																																				
Fuertesimalva chilensis	1	1	1	1	1	1		1	1	1	1	1	1	1	1																		2		2	46
Anredera diffusa				2	2	2	2	2	3		2		2	2																						26
Astrolepis sinuata								2		1	1	2	1	1	1																1		2			26
Krameria lappacea	2	2			2	2			2	2			2		2																					23
Pellaea ternifolia			2					1	2		1			1																						14
Aloysia spathulata											4	4	4	4																						11
Gaya mollendoensis											4	3	4	4																						11
Schkuhria multiflora		1		1			1					1																								11
Solanum paposanum				2	2				2			2																								11
Alternanthera halimifolia											4		3	2																						9
Myriopteris myriophylla							2				2		1																							9
Lycianthes lycioides				4	3			4																												9
Cheilanthes pruinata	1						2																													6
Mostacillastrum gracile	1				2																															6
Heliotropium arborescens var. *grisellum*												2																								3
jatrophetosum macranthae																																				
Jatropha macrantha																2		3	4		3		5		4	2		5		4	5		4	5		34
Senecio yurensis																2	1			1				2	2	2		4								20
Cystopteris fragilis										1												1	1		1			1							1	17
Mentzelia scabra subsp. *chilensis*																															2	2	2	2	2	14
Cheilanthes fractifera																					1					2		1	1							11
Stipa plumosa																																1	1	1	1	11
Companions																																				
Eragrostis nigricans	1	1		4	1	1	1	2	2	1	2				1	1	1	2	1		2	1	1	2	1	2	2	1	3	2	3	2	1	3	1	86
Nama dichotoma		1	1			1		1	1	1	2	1	1	1	1	1	1			1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	80
Solanum peruvianum	2		3						2	4	4	3	2		3	4	2	3	2	3		2	2	5	4	4	3	4	3		4	4	4	3	4	74
Tagetes multiflora	1	1	1		1	1	1		1			1		1	1	1	1	1	1	2			1	1	1	2	1	1			1		1	2	1	71
Aristida adscencionis	2	2			2	2		1	1	2	1	2	2	2	2	1	1	1				1				1			1		2	2	2	1	2	66
Montiopsis cumingii	1	2	2	1		1	1	2	1	2	1	1	1	1		1	2			1	1		1									1		1	1	60
Cheilanthes arequipensis	1	1		2	2	1	2								1	1	2	1	2	1			1	2	1			2	2		1			2		54
Tarasa rahmerii	1	1	1	1		2	1	2	2	1	1	1	2	2									1							1		1	2	2	2	54
Oxalis megalorrhiza		2	2	2	1	2	2		1	1		1		1		1	1		2	1		1	1		1										1	51
Pectocarya lateriflora	1		2		2		1									2	1	1		1	2	1	2	1	1	2		1	2	1				1		51
Drymaria divaricata				1	1		1		1			1					1	1	1					1	1			1			1			1		37
Ephedra americana		2			2						2		2		2						2	3	2												3	26
Eragrostis peruviana	2	1				1																										2		2	1	17
Gamochaeta americana	1							1			1			1						1									1							17
Paronychia microphylla var. *arequepensis*				3		2		3									2					3														14
Senecio sp. (# 3344)			1					1					1										1										1			14
Balbisia weberbaueri		3		2	4		4																													11
Calandrinia ciliata																		1								1		1	1							11
Hoffmannseggia viscosa var. *egena*																															2	1		1	1	11
Portulaca pilosa																					1											1		2	2	11
Spergularia fasciculata	1		1	2																																9
Allionia incarnata																															2	3				6
Chenopodium incisum						1																									1					6
Cistanthe paniculata																											1			1						6
Heliotropium toratense																																	1	1		6
Plantago limensis	1		2																																	6
Senecio vulgaris																				2										1						6
Tigridia arequipensis																		1	1																	6

Sites 1–15, 31–35 Cerro San Ignacio, Jacobo Hunter district; 16–30 Cerro Llorón, Socabaya district.

Other species: *Gochnatia arequipensis* 4 in 1; *Cheilanthes bonariensis* 1 in 4; *Viguiera lanceolata* 2 in 6; *Senna birostris* var. *arequipensis* 1 in 6; *Crassula connata* 1 in 9; *Lantana scabiosiflora* 2 in 14; *Cristaria multifida* 3 in 34; *Facelis plumosa* 1 in 35.

Appendix 3. *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri*

Relevé number	1	2	3	4	5	6	7	8	9	10	11	
Area (m2)	25	25	25	25	25	25	25	25	25	25	25	
Altitude (m) x 10	2	2	2	2	2	2	2	2	2	2	2	
	6	6	6	6	6	6	6	6	9	9	9	
	0	0	0	0	2	2	2	2	3	3	3	
Slope (°)	7	7	7	7	6	6	6	6	6	6	6	
Aspect	SE	SE	SE	SE	S	S	S	S	S	S	S	
Species #	15	15	15	15	8	12	14	14	12	16	9	
												PC
Character species of class and order												
Ambrosia artemisioides	3	4	4	5	3	5	4	4	4	4	4	100
Tarasa operculata	4	4	2	4	2	1	2	2	3	2	2	100
Opuntia sphaerica				4			3		3	3		36
Ambrosio artemisioidis-Weberbauerocerion weberbaueri												
Weberbauerocereus weberbaueri	5	4	6	6	6	6	5	6	6	5	6	100
Exodeconus pusillus				1		1		1	2	2	2	55
Lycio distichi-Weberbauerocereetum weberbaueri												
Lycium distichum	2		2	2		6	5	5		2		64
Aphyllocladus denticulatus			4	4	2							27
Companions												
Montiopsis cumingii	1	2	2	2	2	1	2	1	4	1	1	100
Tagetes multiflora	1	1	1	1		1	1	1	1	1	1	91
Solanum paposanum	4	2	2	2	2	2	1	2				73
Cristaria multifida	1		1	2		1		1				45
Eragrostis nigricans	4		2			2	1	1				45
Oxalis sp. (# 3537)	1		1		1		1	1				45
Solanum peruvianum	1	1							1	1	1	45
Fuertesimalva chilensis	1	2	1	2								36
Plantago limensis	2	2					1	1				36
Senecio sp. (# 3344)				1		1	1				1	36
Aristida adscencionis						1	2	1				27
Dalea exilis		1		1				1				27
Schkuhria multiflora									1	1	1	27
Crassula connata					1		1					18
Oxalis megalorrhiza									1	1		18
Solanum medians									1	1		18
Tarasa rahmerii	1	2										18
Trixis cacalioides	4	4										18
Urocarpidium albiflorum			1							1		18

Sites: 1–8 Quebrada Escalerilla, Chapi, Polobaya district. 9–11 Chapi, Polobaya

Other species: *Armatocereus riomajensis* 5 in 2; *Haageocereus platinospinus* 3 in 2; *Pellaea ternifolia* 1 in 2; *Eragrostis peruviana* 2 in 3; *Nama dichotoma* 1 in 3; *Corryocactus aureus* 3 in 4; *Ephedra americana* 2 in 9; *Balbisia weberbaueri* 4 in 10;

Appendix 4. *Lycio distichi-Weberbauerocereetum weberbaueri*

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
Area (m2)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Altitude (m) x 10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
	3	3	2	2	2	3	0	5	1	4	4	4	4	4	4	4	4	4	4	
Slope (°)	4	4	2	2	2	4	3	14	3	14	14	14	14	14	14	14	14	14	14	
Aspect	SE	SE	-	-	-	SE	WS W	WS W	WS W	WS W	WS W	WS W	WS W	WS W	WS W	WS W	WS W	WS W	WS W	
Species #	12	7	10	14	14	9	9	15	14	13	13	16	18	11	14	14	12	14	19	
																				PC
Character species of class and order																				
Ambrosia artemisioides	4			5	5	5	6	4	5	5	5	4	5	4	4	5	4	3	4	89
Tarasa operculata		2	4	4	4	2		4	5	6		5	3	3	3	4	4	4	3	84
Corryocactus aureus	4		4	5	4			3	2			2	2		2	3		2	2	63
Opuntia sphaerica		4	2	2	2		2			2		2				2	2	2	1	58
Oreocereus hempelianus											2				2					11
Ambrosio artemisioidis-Weberbauerocerion weberbaueri																				
Weberbauerocereus weberbaueri	4	2		2		4		4		5	4	5	4	6	5	4	5	4	5	79
Exodeconus pusillus				2	2		2									2			2	26
Cantuo volcanicae-Weberbauerocereetum weberbaueri																				
Cantua volcanica	2		2		2	3			2		2		2	3	2		2	3		58
Tecoma fulva subsp. *arequipensis*										2	3		5		2		5	5		32
Companions																				
Eragrostis nigricans	6	6	6	6	6	6	5	4	5	4	5	5	4	5	4	5	4	5	5	100
Tarasa rahmerii				1				2	3	3	2	4	4	4	2	2	4	1	1	68
Pectocarya lateriflora				2				2	4		3	2	3	2	2	4	4	4	2	63
Chenopodium incisum			1	2		2			2			5	5	4	4	6		4	3	58
Encelia canescens	4	4	3	4	4	4	4							2			2		4	53
Heterosperma diversifolium								2		3		4	3		1	4	4	2	2	47
Aristida adscencionis		4	5	5	5			2	4	4	5									42
Plantago linearis											3	1	2	2	2	4			3	37
Chenopodium petiolare							4	3	2	2	2								2	32
Allionia incarnata								2	2	2	2					1				26
Ephedra americana	4			5	2			5				4								26
Nicotiana paniculata													3	2			2		2	21
Portulaca pilosa		2		2							2							2		21
Hoffmannseggia viscosa var. *egena*	2		2												1					16
Cristaria multifida						2	2													11
Nama dichotoma													1					1		11
Paronychia microphylla var. *arequepensis*					2				2											11
Suaeda foliosa	2											4								11

Sites 1–19 AGC - Lara, Socabaya district.

Other species: *Atriplex myriophylla* 2 in 1; *Eragrostis peruviana* 2 in 5; *Atriplex semibaccata* 2 in 8; *Senecio vulgaris* 1 in 7; *Chondrosum simplex* 4 in 5; *Helogyne apaloidea* 6 in 7; *Malva parviflora* 1 in 10; *Solanum peruvianum* 3 in 12; *Mostacillastrum gracile* 2 in 13; *Cheilanthes arequipensis* 1 in 13; *Erigeron bonariensis* 1 in 14; *Prosopis laevigata* var. *andicola* 7 in 19

Appendix 5. *Cantuo volcanicae-Weberbauerocereetum weberbaueri*

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	
Area (m2)	25	25	25	25	25	25	25	25	25	25	25	25	
Altitude (m) x 10	2	2	2	2	2	2	2	2	2	2	2	2	
	8	8	8	8	8	8	8	8	7	7	7	7	
	5	5	5	5	5	5	5	5	0	0	0	0	
Slope (°)	25	25	25	25	25	25	25	25	10	10	10	10	
Aspect	E	E	E	E	E	E	E	E	E	E	E	E	
Species #	17	20	20	21	19	19	19	18	20	16	16	20	
													PC
Character species of class and order													
Ambrosia artemisioides	5	6	5	5	6	6	6	6	6	6	6	6	100
Tarasa operculata	3	2	2	2	4	4	4	4					67
Opuntia sphaerica		3			3		2		2				33
Corryocactus aureus				2		2				3	2		33
Ambrosio artemisioidis-Weberbauerocerion weberbaueri													
Weberbauerocereus weberbaueri	6	6	6	4	6	6	4	6	6	4	6	6	100
Exodeconus pusillus				2	2		1	1					33
Paronychio microphyllae-Weberbauerocereetum weberbaueri													
Paronychia microphylla var. *arequepensis*		2	3	2	2		3		4	3	3		67
Dalea exilis	4	4	4	4		2	2		3	1	2	2	83
Pteromonnina ramosa		1	1	1	2		1	2	1		1	1	75
Companions													
Tagetes multiflora	1	1	1	1	1	1	1	1	2	2	1	1	100
Fuertesimalva chilensis	1	1		1	1	2	1	1	1	1	1	1	92
Mostacillastrum gracile	1	1	1	1	1	1	1	1	1	2	1		92
Nama dichotoma	1	1	1	1	1	1	1	1	1	1		1	92
Ephedra americana	3	3	3	2	2	5	2	5			5	3	83
Eragrostis peruviana		2	2	2		2		2	3	2	2	3	75
Gamochaeta purpurea	1	1	1		1	1		1	1		1	1	75
Aristida adscencionis					1	1	1	1	2	1	1	2	67
Eragrostis nigricans	1	1	1	1	3	2	2	2					67
Quinchamalium procumbens	1	1	1	1	3	1	1	2					67
Spergularia fasiculata	2		2	1		1	1		3		2	2	67
Solanum paposanum	2		3	2		3		1		1		2	58
Pellaea ternifolia	1			1	1				1			1	42
Balbisia weberbaueri	4			4		4			4				33
Chondrosum simplex		1				1				1		1	33
Galinsoga parviflora			1						1	1		1	33
Plantago linearis		2					2		3		1		33
Solanum peruvianum			2		2			2		3			33
Oenothera rubida	1								1		1		25
Plantago limensis			1				1	1					25
Tillandsia capillaris									4	3		2	25
Cantua volcanica		4		4									17
Cheilanthes pruinata		1	1										17

Sites: 1–12 Quebrada Peral, Misti volcano slopes, Alto Selva Alegre district.
Other species: *Heterosperma diversifolium* 1; *Facelis plumosa* 1; *Portulaca pilosa* 1 in 12.

Appendix 6. *Paronychio microphyllae-Weberbauerocereetum weberbaueri*

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	
Area (m2)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Altitude (m) x 10	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
	0	0	0	0	0	0	0	0	0	9	9	9	9	9	9	9	9	9	9	9	9	9	2	2	2	1	1	1	2	2	1	1	1	1	1	1	1	
	3	3	3	3	3	1	1	1	1	3	3	3	3	3	7	7	7	7	0	0	0	0	6	6	6	2	3	3	6	6	2	3	9	9	9	9	9	
Slope (°)	5	5	5	5	5	10	10	10	10	8	8	8	8	8	38	38	38	38	34	34	34	34	30	30	30	10	10	10	30	30	10	10	40	40	40	40	40	
Aspect										W	W	W	W	W	S	S	S	S	S	S	S	S	NE	NE	NE	W	W	W	NE	NE	W	W						
	SW	SW	SW	SW	SW	N	N	N	N																								S	S	S	S	S	
Species #	17	13	18	15	17	27	23	21	21	24	17	19	22	18	16	13	16	14	27	23	23	23	21	22	26	26	24	20	20	19	18	19	31	28	23	29	24	
																																						PC
Character species of class and order																																						
Tarasa operculata	2		1	2	1	3	2	3	2	3		2	4		1	2	2	3	2	3	2	2	3	1	2	3	2	2	2	2	2	2	1	1				84
Opuntia sphaerica	3	2	3	4	3	4	4	4	4	2	3	2		2											2	2	2						4	5	3	4	4	57
Ambrosia artemisioides	6	5	5	5	5	4	4	3	4						3	3																						30
Corryocactus aureus																														3		2						5
Corryocaction brevistyli																																						
Corryocactus brevistylus	6	6	6	6	6	6	6	6	6	5	5	4	6	5	6	6	6	5	5	5	6	6	5	5	6	6	6	4	5	5	5	5	5	5	5	4	5	100
Balbisia weberbaueri	4	5	4	4	4	6	6	6	6	4	4	3			5	4		5	4	4	4	4	3	3	4	3	4		4				5	6	6	6	6	81
Mulguraea arequipensis						5	4	4	4							5	5	4				4	5	5	5	5	5			4	4	4						42
Gochnatia arequipensis										4					3		3	2							4	4	3			4	4	4						27
Balbisio weberbaueri-Ambrosietum artemisioidis																																						
Bromus trinii																							4	3			1	2	3	4	4	3	2	4	2	1	3	35
Lupinus cf. *eriocladus*		2		2		2	2			4	6	5	5	6	4		4																					28
Lupinus saxatilis																			3		2							3					4	2	2	2	4	22
Chersodoma juanisernii											1		1						2	2	2	3																16
Cumulopuntia mistiensis		1		1		1	1		1																													14
Senecio phylloleptus																			5	5	4	4						2										14
Cantua candelilla																																			2	2		5
Solanum corneliomulleri																					2							2										5
Companions																																						
Mostacillastrum gracile	1	1	1		1	1	1	1	1	2	2		1	1	2	2	2	1	1	2	1	1	3	2	3	2	2	2	2	2	2	2	2	1	2	1	1	95
Tagetes multiflora	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	1	2	2	1	1	1	1	1		1		92
Plantago linearis	2	2	1	2	1	1		1	1	2	2	1	1	1	1		2	1	2	1	1	2	1	1	1	1	2	2	2		1							76
Pectocarya lateriflora	1		1	1	1	1	1	1	1	1			1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1						68
Cheilanthes pruinata						1	1		1						2	2	2		1	2	1	1			2	1	2			1	1	1	2	2	2	2	1	57
Bowlesia sodiroana	1		1	1	1	1			1				1	1									2	1	1	2	1			1	1	1	1	1	1	1		54
Parietaria debilis	1	1	1	1	1					1		1	1										1	1	1	1	1	1	1				1	1	1	1	1	54
Oxalis megalorrhiza																			2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	51
Spergularia fasciculata										1		1	1						2	2	1	2	2	2				3	3	3	2	2	2	3	4	4	1	51
Tarasa tenuis																			2	1	1	2	2	2	2	3	2	1	2	1	2	2	1	1		2		46
Ephedra americana						4	2	2		2	3	2	3	2					4	2										3	2	2	2	2		2		43
Crassula connata			1										1	1	1		1	1	1	1	1							1					1	1	1	1	1	41
Facelis plumosa	1		1		1	1	1	1	1	1	1	1		1																			1	1		1	1	41
Solanum medians										1	1	1	2						1	1					1	1	1						1	1	1	1	1	38
Descurainia myriophylla																			2			2	2	3	2	2		4	3	2	3	3		2		1		35
Solanum paposanum										1					3	5	5	4	3			2		1		2			2						1			30
Aristida adscencionis	2	1	1	1	2	2	1	1	1	2																												27
Fuertesimalva chilensis						1	1	1	1				2	2	1	2	1	2																				27
Tarasa rhombifolia			1			1				2	1	1	1	1		1				1	1																	27
Cheilanthes arequipensis										1		1	1										1	1	1	1	1		2									24
Diplostephium meyenii																							4						2	4		2	2	3	2	3	3	24
Eragrostis peruviana						2	2	2	1	1	2	2	2	1																								24
Nama dichotoma	1	1	1		1																				1	1	1						2	1				24
Gamochaeta purpurea						2	1	1	1		1	1																							1		1	22
Olsynium junceum															1		1	1												1	1	1	1	1				22
Pellaea ternifolia																									1	1	1			1	1	1	1	1				22
Vulpia myuros																			3	2	2	2	1	2				2	2									22
Gnaphalium dombeyanum																									1	1		2					2	1	2	2	2	22
Gnaphalium lacteum	1		1		1								2																				2		2	1	2	22
Galium aparine						1	1																1	1									1		1		1	19
Grindelia tarapacana						2	2	3	1	4	4		3																									19
Pteromonnina macbridei	1		1	1		1	1	1	1																													19
Tarasa rahmerii										1	1	2	2	1			1	1																				19
Woodsia montevidensis																			2	2	2	1											2	2		2		19
Cryptantha peruviana						1	1	1																	2	2	1											16
Montiopsis cumingii										1		1		1	1	1	2																					16
Oenothera rubida						1	1		1																								1	1	2			16
Senecio tovari																							5	4	4	3	4		4									16
Lobivia pampana																												3	2						3	3	2	14
Tarasa sp.2 (# 3689)	1	1	1	1	1																																	14
Villanova oppositifolia																									1	1	1						2				1	14
Cremolobus chilensis																							1	1												1	1	11
Cuscuta cockerellii																			2	3	2	3																11
Neuontobotrys lanata																			4	3	3	2																11
Oenothera verrucosa																			3	3	2	2																11
Poa asperiflora															1	2	3	3																				11
Polyachyrus sphaerocephalus																																	1		2	1	1	11
Adiantum poiretii																								2				2	1									8
Chenopodium petiolare																			2		2				2													8
Mutisia lanigera																																		1		1	1	8
Senecio yurensis																			2	2		2																8
Viguiera lanceolata																									3	2	2											8
Bartsia serrata																																	1			1		5
Erigeron bonariensis					1			1																														5
Conyza tunariensis													2	2																								5
Coreopsis fasciculata																																		2			1	5
Muehlenbeckia hastulata						2		2																														5
Paronychia microphylla var. *arequepensis*																			3			2																5
Calceolaria inamoena																																				2		3
Gamochaeta americana																																	2					3
Solanum peruvianum										1																												3

Sites: 1–12 Quebrada Peral, Misti volcano slopes, Alto Selva Alegre district; 13–26 Cerro Pacheco, Misti volcano slopes, Alto Selva Alegre district; 27–29 El Viscachal, Polobaya district; 30–32 Cerro Los Andes, Cono Norte, Chachani volcano slopes, Yura district; 33–37 Chiguata, Chiguata district.

Appendix 7. *Balbisio weberbaueri-Ambrosietum artemisioidis*

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	
Area (m2)	64	64	64	64	64	64	64	64	64	64	64	64	
Altitude (m) x 10	2	2	2	2	2	2	3	3	3	3	3	3	
	8	8	8	8	8	8	0	0	0	0	0	0	
	0	0	0	0	0	0	4	4	4	4	4	4	
Slope (°)	45	45	45	45	45	45	10	10	10	10	10	10	
Aspect	N	N	N	N	N	N	N	N	N	N	N	N	
Species #	30	23	24	33	30	28	26	29	26	23	27	22	
													PC
Character species of class and order													
Opuntia sphaerica	2	2	2	2	2	2	5	4	5	4	4	4	100
Tarasa operculata	1	1	1	1		2	1			1	2		67
Corryocactus aureus							2		2			2	25
Ambrosia artemisioides		2				4							17
Corryocaction brevistyli													
Corryocactus brevistylus	5	5	5	4	4	5	4	5	4	4	5	4	100
Balbisia weberbaueri	4	2	3	3	4	2	3	2	4	3	4	2	100
Gochnatia arequipensis	4	4	4	5	6	6	5	5	5	5	5	5	100
Mulguraea arequipensis							5	5	5	5	5	5	50
Aloysio spathulatae-Corryocactetum brevistyli													
Senecio subcandidus	3	2	2	3	3	4		3	3	3	3	3	92
Aloysia spathulata		3		2	4			4	2	4	4	3	67
Senna birostris var. *arequipensis*	2		3				1	1	2		2		50
oenotheretosum rubidae													
Pectocarya lateriflora	1	1	1	1	2	2							50
Oenothera rubida	1	1	1		1	1							42
Villanova oppositifolia	2	1	2	1	1								42
Kageneckia lanceolata	5	5	3		2								33
Lantana scabiosiflora	3	2		2	3								33
Heliotropium toratense	3	2			1	2							33
Croton ruizianus	4	4	4										25
Bomarea ovata	2	1	2										25
Cremolobus chilensis				1	1	1							25
Gaya mollendoensis	2		2	2									25
Heterosperma diversifolium				1	1	1							25
Nama dichotoma				1	1	1							25
Paronychia microphylla var. *arequepensis*	2	2		2									25
Tigridia arequipensis	1	1		1									25
Chondrosum simplex	1		1										17
Erigeron bonariensis				1		1							17
Fuertesimalva chilensis					1	1							17
Gilia laciniata				1	1								17
Grindelia tarapacana	1			1									17
Lupinus misticola				2	2								17
Solanum paposanum	1				2								17
Solanum peruvianum				2		2							17
Tecoma fulva subsp. *arequipensis*			3		3								17
adesmietosum augusti													
Pectocarya anomala							1	1	1	1	1	1	50
Pellaea ternifolia				1				1	1	1	1	1	50
Adesmia augusti							2	1	2	2		2	42
Diplostephium meyenii								3	3		3	3	33
Plantago linearis							1	1		1	1		33
Spergularia fasciculata							1	2			2	1	33
Austrocylindropuntia subulata							4		4		5		25
Poa asperiflora								2		1	2		25
Companions													
Bowlesia sodiroana	1	1	1	2	2	1	2	1	1	2	1	2	100
Tagetes multiflora	1	1	1	1	1	1	1	1		1	1	1	91
Eragrostis peruviana	2	3	2	1	2		2	1	2	1	2		83
Aristida adscencionis				3	1	1	2	1	1	1	2	1	75
Cheilanthes pruinata	2	2	2	2	2	1	2	2	2				75
Tarasa rahmerii	1	1	1	1	1	1	1	1	1				75
Drymaria divaricata				1	1	1		1	1	1	1	1	66
Eragrostis nigricans						1	1	2	2	1	1	1	58
Facelis plumosa				1		1	1	1	1		1	1	58
Mostacillastrum gracile	1		1		1			1	1	1		1	58
Lycianthes lycioides	3		2	3			2				3	3	50
Ephedra americana				2			3	3	2	2			42
Galinsoga parviflora						1	1	1		1	1		42
Pteromonnina macbridei				1			1	1		1	1		42
Galium aparine						1	1	1	1				33
Portulaca pilosa	1		1						1		1		33
Gamochaeta americana	1				1							1	25

Sites: 1–6 Cerro Pajonal, Mollebaya district. 7–12 Pampa Culanayoc, Pocsi district.

Other species: *Cystopteris fragilis* 2 in 5; *Crassula connata; Paronychia setigera* 1 in 6.

Appendix 8. *Aloysio spathulatae-Corryocactetum brevistyli*

CHAPTER 3

Andean shrublands of Moquegua, South Peru: Prepuna plant communities

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Phytocoenologia 42: 29–55, 2012

Abstract

A syntaxonomic overview of shrubland vegetation in the southern Andean regions of Peru is presented. For each plant community, information is given on physiognomy, floristic diversity, ecology and geographical distribution. The shrub vegetation on the slopes of the upper Tambo river valley includes annual herbs, grasses, cacti and ferns. In total, 151 vascular species have been documented from forty-six relevés made at altitudes between 3470 and 3700 m. After classification with TWINSPAN, one class, one order, one alliance, three associations, two subassociations *typicum* and three subassociations, one variant, and two communities are distinguished.

Hierarchically the class *Echinopsio schoenii-Proustietea cuneifoliae* comprises the order *Echinopsio schoenii-Proustetalia cuneifoliae*, and the alliance *Salvion oppositiflorae*, occurring in the Prepuna dwarf scrubs. Within the alliance the following 3 new associations (with subassociations) have been distinguished: *Senecioni arnaldii-Exhalimolobetum weddellii* (thorny rosette-like dwarf shrubs), *Mostacillastro gracile-Chuquiragetum spinosae* (high cover of shrubs) and *Anredero diffusae-Diplostephietum meyenii* (high cover of clustered columnar cacti and patches of thorny shrubs).

Two communities have been distinguished: *Cylindropuntia rosea*[3] and *Helogyne apaloidea*[4], and the community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*, which includes several introduced species growing on heavily grazed wet slopes. The basal communities of *Stipa ichu* and *Nassella asplundii* have been also identified.

The most diverse families are Asteraceae, Poaceae and Cactaceae, followed by Solanaceae and Fabaceae. The vegetation includes endemic, native and a few introduced species.

DCA was used to interpret the correlation between environmental variables and species composition. Species composition is best explained by altitude, inclination and vegetation cover.

Key words: Prepuna, floristic diversity, phytosociology, syntaxonomic classification, *Echinopsio schoenii-Proustietea cuneifoliae*, Andes, Peru.

3 The correct name of the species is *Cylindropuntia rosea* and not *Opuntia rosea* according to a detailed taxonomical analysis by Montesinos-Tubée (2013b).

4 The correct name of the species is *Helogyne apaloidea* and not *Helogyne ferreyrae* according to a detailed taxonomical analysis done in 2015 at USM herbarium.

Introduction

A large diversity of plant communities can be found in the southern Peruvian Andes, in dry valleys, highland mountain valleys, grassland plateaus, highland cushion bogs, lakes and subnival summits. The altitude, topography and geology in the Andes are very diverse, which results in a complex biogeography. There are numerous descriptions of Andean biogeography and vegetation of the 'puna'. In the first general extended treatment about the vegetation of the Andes, Weberbauer (1945) refers to the 'puna' as the highest point of the Andes without agriculture and differentiates it from the altiplano plateaus which are more likely to bedominated with dwarf grasses and rosette and cushion plants'. For the evergreen resin shrub formations occurring above 4200 m, Weberbauer (1945) uses the term *tolares* when referring to the communities conformed by species of *Baccharis* and *Parastrephia*.

Previous studies have not revealed the ecology and vegetation structure of the high Andes of Moquegua. A general overview of the floristics of the upper Tambo river slopes was given by Montesinos-Tubée (2007a, 2011a), who also presented studies on cacti and succulents (Montesinos-Tubée 2007b, 2010b). More recently, Schwarzer et al. (2010) presented a study on the dispersal and divergence of plant species of the Huaynaputina pumice slopes of Moquegua. Most of the studies carried out in the Peruvian Central and South Andes, the Bolivian Andes, northern Chile and southwest Argentina provide information on Andean vegetation (Weberbauer 1945; Ferreyra 1960, 1987; Ruthsatz 1977; Rivas-Martínez & Tovar 1982; Gutte 1988; Seibert & Menhofer 1992; Navarro 1993; Pestalozzi & Torrez 1998; Luebert & Gajardo 2000; Arakaki & Cano 2003; Galán de Mera et al. 2003, 2009).

In the traditional vegetation classification for Bolivia, the term 'puna' is used for the highlands of the Central Andes at an altitude of between 3600 and 4100 m (Beck 1985, 1998; Beck & Garcia 1991). Kuentz et al. (2007) characterise the southern Andes of Peru as mountainous steppe and puna, and consider the puna to be dry vegetation located on the Altiplano and on the mountain slopes, above 3000 m. Wilson (1988) considered the arid and humid valleys of the Andes of South Peru to be biogeographical islands. They contain many endemic species and are isolated from other such valleys by high cold desert-like Andean ridges, a situation favouring speciation and, hence, increased biodiversity.

The vegetation formations in the South Peruvian Andes (from 15° S to 28° S) are dominated by different growth forms that include bunch grasses, herbs and rosettes, succulents, and shrubs, trees and cushion plants (Udvardy 1975). Several authors have classified the Andean regions according to the climate and vegetation. In the present study, we follow the phytoecological classification that corresponds to Rivas-Martínez & Tovar (1983), Huber & Riina (1997) and Kuentz et al. (2007). Our study presents the Prepuna as characterised by dense shrubby vegetation with cacti and succulents, annual herbs and ferns.

As in other parts of South America, the Andes of South Peru are suffering from rapid population growth, which is accompanied by more livestock and thus overgrazing. The fragile ecosystems of the South Peruvian Andes are vulnerable to the urban population increase and the expansion of anthropogenic environmental degradation; the lack of environmental awareness, the mining activities and climate change are directly or indirectly leading to biodiversity change and to the migration of species. Fortunately, many sites still appear to be undisturbed.
To date, the only studies done of the biodiversity of the Andes of Moquegua are those by Arakaki & Cano (2003), Schwarzer et al. (2010) and Montesinos-Tubée (2011a). The main objective of the present study was to identify, classify and ecologically interpret the vegetation growing on rocky slopes near the Tambo river valley in Moquegua. The study was carried out within the framework of a broader project involving floristic and ecological research at higher altitudes in the Andes of Moquegua.

Study area

Geography

The headwaters of the Tambo river basin valley are located northeast of the Ubinas volcano, in General Sánchez Cerro province, approximately 105 km south of Moquegua city, in the south of Peru (Fig. 1). In these regions the Andean mountain slopes of the Prepuna are found at an altitude of approximately 3400–3900 m.
The sites studied are located in the lower shrublands or Prepuna, at an altitude of between 3470 and 3700 m and lie between the areas of Toreqaqa' area (16° 15' 16" S; 70° 45' 07"W) and 'Sefincane' (16° 10' 08"S; 70° 39' 44"W). Given that the geography and vegetation of the Moquegua region are similar to those of the phytogeographical puna belts of Arequipa described by Kuentz et al. (2007), we describe them as straddling the boundary between the mountainous steppe and the puna.

Climate

The climate between Ubinas and Ichuña towns is mostly dry with a marked seasonal rainy period. According to the meteorological stations at Ubinas (3200 m) and Ichuña (3800 m), during 2008 and 2009, reported an annual precipitation of 243 mm/year in Ubinas and 460 mm/year in Ichuña. During the year, the average relative humidity is 20–30%. Temperatures remain low throughout the year: the mean minimum temperature is 3.7 °C and the mean maximum is 19.4 °C. The lowest temperature recorded is –8 °C in the month of July and the highest 24.4 °C in the month of October and the mean annual temperature is 11.6 °C. Mean wind direction in 2008 and 2009 was S to SSE and the average windspeed was 6 km/h. As can been seen in graph 2, compiled from data from 2008 and 2009, the temperature and rainfall averages differ from those found in the central Andes. Data obtained from the Servicio Nacional de Meteorología e Hidrología del Perú (2009). The Atacama Desert conditions also occur in the south of

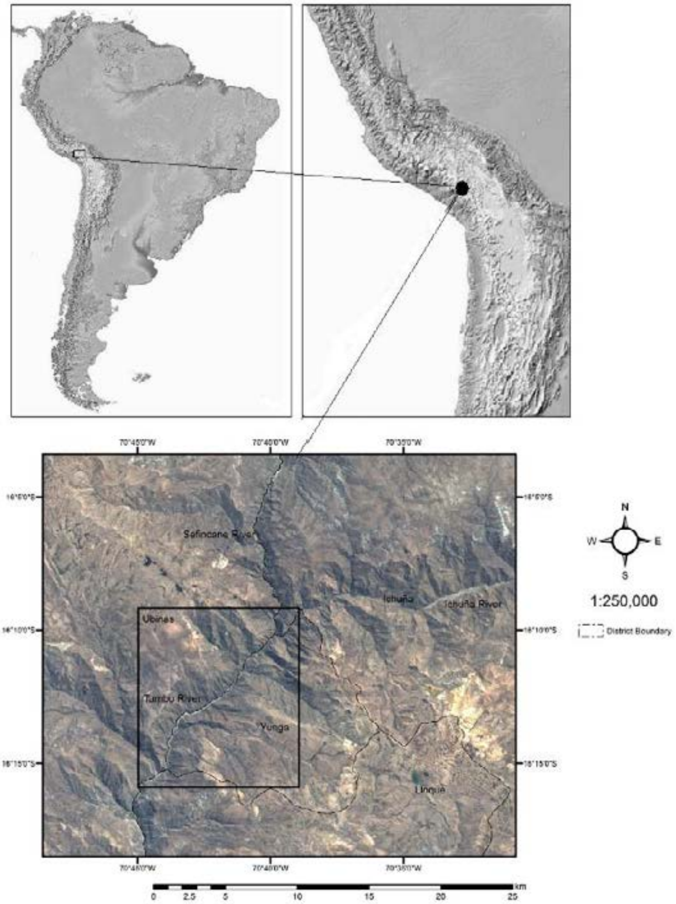

Figure 1. Location of the upper reaches of the Tambo River in the Andes of Moquegua, Peru. Image source: Landsat 7 Enhanced Thematic Mapper (ETM+) Acquisition date = 10 May, 2001.

Moquegua (South Peru) but do not have a strong influence over the climatic conditions of North Moquegua, even so the hyperaridity is attributed to a combination of global climate cooling and enhanced upwelling of the Humboldt Current (Hartley 2003). In the other hand, above 4800 m snowline may occur but it shows trends that occasional incusrsion of precipitation linked to cutoff lows does not cause a westward depression of the regional snowline, even at extreme altitudes (Haselton et al. 2002).

Geology

The study area is characterised by two subgroups of strongly dissected and eroded volcanic materials: 1. fairly widespread deposits from the Tertiary and Quaternary that accumulated during the formation of the arc of volcanoes in the south of Peru, 2. older volcanic deposits from the upper Jurassic and lower Cretaceous. In addition, on the

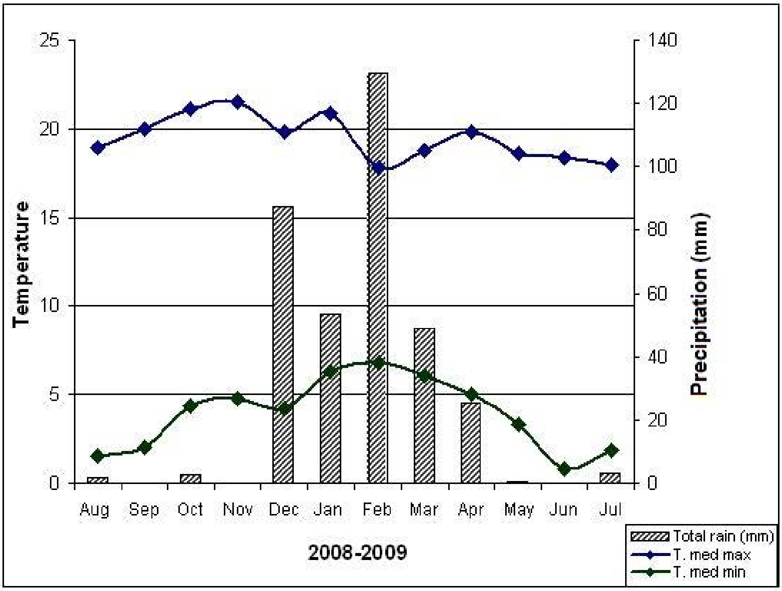

Figure 2. Climatic data from Ubinas town (3200 m) for 2008 and 2009.

altiplano there are outcrops of igneous rock that were formed some time from the upper Cretaceous to lower Tertiary (Allmendinger et al. 1997). Weathering and erosion have created two major landscape units: the 'altiplano' and the steep slopes of the puna. In our studied areas clayey and silty soils are characteristic.

Background studies

Phytosociological studies of the vegetation of the South Central Andes have been done in the north Chile (Villagrán et al. 1981; Luebert & Gajardo, 2000, 2005; Lambrinos 2006; Luebert & Pliscoff 2008), southwest Bolivia (Navarro 1993; Seibert & Menhofer 1991, 1992, 1993; Gutte 1995), Bolivia (Navarro & Maldonado 2002) and Argentina (Ruthsatz, 1977; Ramírez & Figueroa 1987; Conticello et al. 1996). Descriptions of plant communities in the Andean regions of South Peru are available from Gutte & Müller (1985), Galán de Mera & Vicente Orellana (1996), Galán de Mera & Gómez Carrión (2001), Galán de Mera et al. (2002a,b 2003, 2009, 2010). Studies on the Andean regions of Central Peru are: Gutte (1978, 1980, 1985, 1986, 1987, 1988), Rivas-Martinez & Tovar (1982), Müller & Gutte (1985) and Galán de Mera et al. (2004).

Methods

Vegetation sampling

The Andean shrubland of the upper Tambo River, Moquegua (General Sanchez Cerro Province) was studied along the altitudinal gradient on both sides of the river valley with different gradient and aspect. Prior to the selection of relevés, a four-day survey was done to select the sites randomly, taking into account the homogeneity of the vegetation and accessibility. The study area was divided into four sites: (A) Jatuntio, Arapa and Sefincane, (B) Chojo and S/N slopes (Qaqahuara), (C) Toreqaqa and Yanarico, (D) Huañasco and Sicunaya (Figure 1). Site A consists of 1. the canyon-like steep slopes ('Jatuntio' and 'Arapa'),on the left side of the streams of the Tambo River north of Yunga town, called and 2. the uniform slopes of Sefincane at the confluence of the rivers Tambo and Sefincane. Site B belongs to 1. the slopes of Chojo in the north of Pampilla and 2. the north and south slopes (Qaqahuara mountain) near the town of Pampilla, near the path connecting Camata and Tassa. Site C corresponds to the slopes downstream of the Tambo river at the base of the alluvial fans of the central lower parts of the mountains (Toreqaqa and Yanarico), south of Camata and Exchaje towns, north of the confluence between the Yarihualla and Tambo rivers. Sector D comprises mountain slopes of Huañasco and Sicunaya site, southeast of Pampilla town.

In these sites the shrublands between 3470 and 3700 m were surveyed. The Andean shrubland study was done with a total of 46 relevés from the slopes of the upper Tambo river basin (Fig. 1). The 46 relevés were selected carefully, taking into account the homogeneity and minimal area of the vegetation, and using the methodology followed by the Zurich-Montpellier School (Braun Blanquet 1979; Van der Maarel 2004). To avoid undersampling dormant species, relevés were made during the optimal development of the vegetation (March and April 2009). The relevés were usually slightly bigger than the minimal area (Knapp 1984; Wikum & Shanholtzer 1978). The following plot sizes were used: 20 m² for dwarf shrublands; 25 m², 30 m², 36 m² and 50 m² for sites where the shrubs were taller and there was more vegetation cover, and 225 m² in the case of one relevé with tree cover. All relevés consisted of the same general type of vegetation, typically occurring on rocky slopes with relatively dense cover and with similar species composition.

For each relevé, the species presence was noted and cover was estimated in percentages (Knapp 1984), and later transformed for computer calculations (classification and ordination) to the ordinal nine-point scale of Van der Maarel (1979). The scales were: 0–2% =1, 2–3%=2, 3–4%=3, 4–8%=4, 8–18%=5, 18–38%=6, 38–68%=7, 68–88%=8 and 88–100% = 9.

Species identification

The unknown plant species were sampled, assigned a code corresponding to the collection site, labelled and dried for further identification. We used various ibliographical

information and taxonomical keys for the species identification (Weberbauer 1945, Ferreyra 1987; Brako & Zarucchi 1993; Montesinos-Tubée 2007a, 2011a) and we also differentiated species distribution by comparing the species distribution we found with that found by other studies (Asociación Especializada para el Desarrollo Sostenible 1998; Arakaki & Cano 2003; Franco et al. 2004; Gobierno Regional de Tacna 2007; Galán de Mera et al. 2003, 2009; Schwarzer et al. 2010).
The botanical material was processed and identified in USM, MOL, HUSA, MOL, MO, F and L herbariums. The online botanical databases of the South American flora from the Missouri Botanical Gardens, the Field Museum of Natural History and the Chile floristic database were also consulted. Specimens were sent to specialists at other institutions, to confirm their taxonomical nomenclature.
Photographs have been taken. Plant specimens were collected under the number of the first author; they have been stored at USM, HUPCH, CUZ, CPUN, MO and WAG.

Soil sampling and analysis

Bulked soil samples for pH analysis were taken from all the 46 relevés from the upper 5 cm of the topsoil. In each relevé 5 subsamples were taken, mixed, dried and weighed. Soil pH was ascertained by taking a 10 g subsample of each dried soil sample, adding 10 cl of H_2O (distilled water), mixing with a spatula and measuring the pH with a digital meter.

Data processing

The vegetation was classified using TWINSPAN (Hill 1979). As well as a full syntaxonomic table, a synoptic table of presence classes was processed. The cover-abundance values of each species in the relevés was estimated using the ordinal nine scale as modified by Van der Maarel (1979). The mean characteristic cover was measured by the mean cover of a species over the relevés in which it occurs within the particular cluster.
Indirect ordination (DCA, CANOCO 4.5; Ter Braak & Šmilauer 2002; Lepš & Šmilauer 2003) was used to study the relation between species composition and environmental variables (Sýkora, 2007). Samples of the communities were enveloped according to the clusters as distinguished with TWINSPAN. In the DCA diagram, the sample 46 (considered as an outlayer), was excluded from the analysis.

Syntaxonomy

The syntaxonomy of the shrubland communities was classified using the phytocoenological classification of Rivas-Martínez & Tovar (1983). The description of the shrubland communities is based on shrubs, cacti and herbs, rather than on lichens, mosses and algae, which are infrequent in the study area.
The floristic affinities with previously described syntaxa were ascertained and the syntaxonomy was further studied following the Zurich-Montpellier approach (Braun-

Blanquet 1979, Kent & Coker 1992) and the international Code of Phytosociological Nomenclature (Weber et al. 2000; Izco & Del Arco 2003; Izco 2004).
To describe the new syntaxa we compared the most recent phytosociological classification of the Peruvian, Bolivian, Chilean and Argentinian Andean plant communities, and evaluated our community affinities with them in order to decide to what extent our communities could be integrated into them.

Results

Floristic composition and growth form

A total of 151 species, belonging to 125 genera and 50 families of vascular plants were recorded from 46 relevés in 6 sites of the Andean shrublands of the upper basin of the Tambo River, Moquegua. Table 2 lists the number of families, genera and species and the most species-rich families, per community.

Table 1. Overview of parameters for each research site (A-D) in the Prepuna of the Andes of Moquegua, Peru. Altitude, relevé size, local sector, slope, number of species, pH, vegetation cover and soil depth (in cm).

Site	Alt.(m)	Relevé	Sector	Rel. (field numb.)	Rel. Size (m2)	Slope	Degree	Num spp	pH	Soil depth (cm)	Veg Cov
	3580	1	Sefincane	YSE1	25	W	32	28	6,2	40	75
	3580	2	Sefincane	YSE2	25	W	35	34	6,4	40	82
	3580	3	Sefincane	YSE3	25	W	35	44	6,4	26	90
	3580	10	Jatuntio	YJA4	25	NNE	47	39	7,2	4	75
	3580	12	Jatuntio	YJA1	25	NNE	43	33	6,5	4	70
	3590	4	Sefincane	YSE4	25	NW	45	41	6,0	12	80
A	3590	13	Jatuntio	YJA2	25	NNE	46	29	7,0	5	83
	3600	11	Jatuntio	YJA5	25	NNE	44	36	6,5	5	75
	3610	5	Sefincane	YSE5	20	NW	42	35	6,5	16	70
	3620	9	Jatuntio	YJA3	25	NNE	45	37	7,3	4	85
	3660	6	Arapa	YAR1	25	NE	40	38	6,6	13	85
	3680	7	Arapa	YAR2	25	NE	47	40	5,9	4	90
	3700	8	Arapa	YAR3	25	NE	47	40	6,1	6	72
	3700	14	Arapa	YAR4	25	NE	45	28	6,1	15	70
	3560	15	Qaqahuara P	QFP1	25	S	39	42	6,3	9	80
	3560	16	Qaqahuara P	QFP5	25	S	35	30	5,1	20	60
	3570	20	Qaqahuara P	QFP2	25	NE	50	53	7,4	11	80
	3570	22	Qaqahuara P	QFP4	25	NE	46	41	7,9	18	62
	3580	21	Qaqahuara P	QFP3	25	SE	45	42	8,0	11	80
	3610	24	Chojo	PCH1	36	NW	45	25	7,8	30	75
	3630	19	Qaqahuara Y	QFY3	25	E	40	36	7,3	16	65
B	3640	17	Qaqahuara Y	QFY1	50	SE	45	29	5,6	8	45
	3640	23	Qaqahuara Y	QFY4	25	SE	43	32	8,0	15	70
	3640	25	Chojo	PCH2	36	NW	55	34	7,9	20	60
	3640	26	Chojo	PCH3	36	NW	43	37	7,8	30	80
	3650	27	Chojo	PCH4	36	NW	48	35	7,8	20	75
	3650	30	Qaqahuara Y	QFY5	25	SE	38	21	8,0	12	70
	3660	18	Qaqahuara Y	QFY2	50	SE	43	32	6,9	6	65
	3670	28	Chojo	PCH5	36	NW	43	33	7,9	10	70
	3700	29	Chojo	PCH6	36	NW	42	31	7,7	20	80
	3470	40	Toreqaqa	EXC1	36	NNW	7	43	5,8	35	75
	3480	41	Toreqaqa	EXC2	25	NW	20	48	7,8	40	80
	3500	37	Toreqaqa	EXC3	25	W	30	54	7,4	40	73
	3500	38	Toreqaqa	EXC4	25	W	12	56	5,7	40	68
	3520	33	Yanarico	CAY3	36	SE	30	31	6,4	5	72
C	3520	39	Toreqaqa	EXC5	25	NW	12	46	7,3	40	65
	3530	31	Yanarico	CAY1	36	NE	49	18	6,9	8	68
	3530	32	Yanarico	CAY2	36	NE	38	23	6,9	10	72
	3530	34	Yanarico	CAY4	36	SE	18	36	6,6	10	62
	3530	35	Yanarico	CAY5	36	SE	43	27	6,3	8	65
	3540	36	Yanarico	CAY6	36	SE	48	27	6,7	16	81
	3580	42	Huañasco	PHU4	30	NE	8	31	7,7	12	75
	3590	45	Huañasco	PHU3	30	W	40	30	6,0	22	34
D	3600	44	Huañasco	PHU2	30	N	43	33	6,0	10	40
	3610	43	Huañasco	PHU1	30	N	43	32	5,1	20	35
	3700	46	Sicunaya	PES1	225	N	40	50	7,8	20	80
Average	3595				34		40	36	6,8	17	71

Table 2. Most diverse plant families and genera of the Prepuna, Moquegua, Peru

FAMILY	# GENERA	# SPP	GENERA	# SPP.
ASTERACEAE	31	37	*Bomarea*	3
POACEAE	10	12	*Calceolaria*	3
CACTACEAE	6	9	*Cheilanthes*	3
SOLANACEAE	6	7	*Chenopodium*	3
FABACEAE	5	5	*Cumulopuntia*	3
PTERIDACEAE	3	5	*Perezia*	3
AMARANTHACEAE	2	4	*Solanum*	3
BRASSICACEAE	4	4	*Tagetes*	3
MALVACEAE	2	4	*Tarasa*	3

In Table 3 a growth form spectrum is given per community. The most numerous species in all communities are herbs followed by shrub species. Overall, 8% of the total number of species are represented by Poaceae (12 species); 11% by succulents (including, Cactaceae, Basellaceae, Crassulaceae); 6% by ferns (9 species) and 3.3% by parasitic or hemiparasitic herbs and shrubs (Loranthaceae, Santalaceae, Scrophulariaceae). Of all herbs, 33% (50 species) consist of common annual herbs (they include native and introduced), 3.3% of vines or climbers, 5.3%, of geophytes (*Stenomesson* sp. (# 2107)[5], *Sisyrinchium bracteosum, Oxalis* spp., *Nothoscordum* spp., *Olsynium junceum* and *Zephyranthes boliviana*[6]), 4% of ground rosettes and 3% of plants with densely pubescent leaves and stems (*Gnaphalium* spp., *Gamochaeta* spp.).

Shrubland plant communities

After interpretation of the TWINSPAN table five plant communities were distinguished and assigned to one alliance, one order and one class (Table 4). The Prepuna vegetation communities recognised in the Andes of Moquegua are summarised as follows:

Echinopsio schoenii-Proustietea cuneifoliae Montesinos, Cleef & Sýkora 2012
Echinopsio schoenii-Proustietalia cuneifoliae Montesinos, Cleef & Sýkora 2012
Salvion oppositiflorae Montesinos, Cleef & Sýkora 2012
1. *Senecioni arnaldii-Exhalimolobetum weddellii* Montesinos, Cleef & Sýkora 2012
2. *Mostacillastro gracile-Chuquiragetum rotundifoliae* Montesinos, Cleef & Sýkora 2012
2.1. *phacelietosum pinnatifidae* Montesinos, Cleef & Sýkora 2012
2.2. *chuquiragetosum rotundifoliae* Montesinos, Cleef & Sýkora 2012 = subass. typicum
2.3 *chaptalietosum similis* Montesinos, Cleef & Sýkora 2012
3. *Anredero diffusae-Diplostephietum meyenii* Montesinos, Cleef & Sýkora 2012
3.1 *diplostephietosum meyenii* Montesinos, Cleef & Sýkora 2012 = subass. typicum

5 Identified as *Stenomesson* sp. (# 3871) (A. Meerow 2013, pers. comm., 17 December).
6 Identified as *Zephyranthes boliviana* (W. Torres & W. Galiano 2013, pers comm., 16 December).

Table 3. Number of species per growth form for each association and community.

Growth forms	1. *Senecioni arnaldii-Exhalimolobetum weddellii*		2. *Mostacillastro gracile-Chuquiragetum rotundifoliae*		3. *Anredero diffusae-Diplostephietum meyenii*		4. Community of *Cylindropuntia rosea* and *Helogyne apaloidea*		5. Community of *Escallonia myrtilloides* and *Ophryosporus heptanthus*	
	#	%	#	%	#	%	#	%	#	%
Trees	--	--	--	--	--	--	--	--	1	2.4
Shrubs	17	16.7	20	23.3	11	15.7	4	12.5	5	12.2
Spiny shrubs	6	5.9	5	5.8	4	5.7	3	9.4	1	2.4
Succulents	10	9.8	8	9.3	8	11.4	4	12.5	3	7.3
Grasses	9	8.8	7	8.1	6	8.6	4	12.5	7	17.1
Herbs	41	40.2	27	31.4	26	37.1	13	40.6	18	43.9
Climbers	5	4.9	3	3.5	4	5.7	1	3.1	--	--
Bulbs	4	3.9	3	3.5	2	2.9	1	3.1	1	2.4
Parasite / hemi-parasite	3	2.9	5	5.8	4	5.7	2	6.3	3	7.3
Ferns	7	6.9	8	9.3	5	7.1	--	--	2	4.9
Total	102		86		70		32		41	
Number of relevés	16		13		12		4		1	

3.2 *bomaretosum ovatae* Montesinos, Cleef & Sýkora 2012
3.3 variant of *Calceolaria pisacomensis*
4. Community of *Cylindropuntia rosea* and *Helogyne apaloidea*
5. Community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*

Echinopsio schoenii-Proustietea cuneifoliae Montesinos, Cleef & Sýkora
Typus: *Echinopsio schoenii-Proustietalia cuneifoliae* Montesinos, Cleef & Sýkora
Physiognomy and distribution: Shrubland (1–2 m), Prepuna, as natural stands nearrocky scree slopes. This shrubby vegetation is found in the Andean valleys in the upper Tambo river in Moquegua Department, Peru, which is volcanically active (Ubinas volcano) and is characterised by soils developed on alluvium or on volcanic deposits. The stands are of very species-rich vegetation with several endemics and native species among the herbs, grasses, cacti and shrubs. The vegetation cover exceeds 60% and contains 74 species on average. The presence of some ruderal species is evidence of degradation in some areas. We have defined this unit based on the high vegetation cover, unique presence of species (among endemics and natives) that are characteristic of the Moqueguan upper valleys and on the basis of its difference from other such communities in terms of climatic conditions, topography and geology. Compared with other Andean valleys, the upper Tambo river valleys are influenced more by the altiplano climatic system and receive more rainfall. The high frequency of species that are not found in comparable communities elsewhere indicates that the upper Tambo river valley is a distinct Andean ecosystem, more humid and richer in species composition.
Syntaxonomy and composition: The most diverse families are Asteraceae, Cactaceae, Fabaceae, Pteridaceae, Poaceae and Lamiaceae. Characteristic species for the class and order: *Aa mathewsii, Adesmia miraflorensis, Bowlesia sodiroana, Cheilanthes myriophylla, Chenopodium incisum, Dalea cylindrica, Echeveria peruviana, Echinopsis schoenii,*

Table 4. Phytosociological table of the Andean shrublands of Prepuna in Moquegua, Peru. 1: ***Senecioni arnaldii-Exhalimolobetum weddellii***; 2: ***Mostacillastro gracile-Chuquiragetum rotundifoliae***; 2.1: ***phacelietosum pinnatifidae***; 2.2: ***subassociation typicum***; 2.3: ***chaptalietosum similis***; 3: ***Anredero diffusae-Diplostephietum meyenii***; 3.1: ***subassociation typicum***; 3.2: ***bomaretosum ovatae***; 3.3: variant of ***Calceolaria pisacomensis***; 4: Community of ***Cylindropuntia rosea*** and ***Helogyne apaloidea***; Community of ***Ophryosporus heptanthus*** and ***Escallonia myrtilloides***. Relevés underlined indicate typus. CS for the characteristic species from those higher syntaxonomical units of literature.

Relevé number	1	2	<u>3</u>	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	<u>20</u>	21	22	23	24	25	26	27	28	29	30	31	32	33	<u>34</u>	35	36	37	38	39	40	41	42	43	44	45	46
Relevé (field number)	YS E1	YS E2	YS E3	YS E4	YS E5	YA R1	YA R2	YA R3	YJ A3	YJ A4	YJ A5	YJ A1	YJ A2	YA R4	QF P1	QF P5	QF Y1	QF Y2	QF Y3	QF P2	QF P3	QF P4	QF Y4	PC H1	PC H2	PC H3	PC H4	PC H5	PC H6	QF Y5	CA Y1	CA Y2	CA Y3	CA Y4	CA Y5	CA Y6	EX C3	EX C4	EX C5	EX C1	EX C2	PH U4	PH U1	PH U2	PH U3	PE S1
Altitude (x10)	358	358	358	359	361	366	368	370	362	358	36	358	359	370	356	356	364	366	363	357	358	357	364	361	364	364	365	367	370	365	353	353	352	353	353	354	350	350	352	347	348	358	361	360	359	370
Inclination	32	35	35	45	42	40	47	47	45	47	44	43	46	45	39	35	45	43	40	50	45	46	43	45	55	43	48	43	42	38	49	38	30	18	43	48	30	12	12	7	20	8	43	43	40	40
Orientation	W	W	W	NW	NW	NE	NE	NE	NNE	NNE	NNE	NNE	NNE	NE	S	S	SE	SE	E	NE	SE	NE	SE	NW	NW	NW	NW	NW	NW	SE	NE	NE	SE	SE	SE	SE	W	W	NW	NNW	NW	NE	N	N	W	N
Area (m²)	25	25	25	25	20	25	25	25	25	25	25	25	25	25	25	25	50	50	25	25	25	25	25	36	36	36	36	36	36	25	36	36	36	36	36	36	25	25	25	36	25	30	30	30	30	225
% vegetation cover	75	82	90	80	70	85	90	72	85	75	75	70	83	70	80	60	45	65	65	80	80	62	70	75	60	80	75	70	80	70	68	72	72	62	65	81	73	68	65	75	80	75	35	40	34	80
pH	6.2	6.4	6.4	6.0	6.5	6.6	5.9	6.1	7.3	7.2	6.5	6.5	7.0	6.1	6.3	5.1	5.6	6.9	7.3	7.4	8.0	7.9	8.0	7.8	7.9	7.8	7.8	7.9	7.7	8.0	6.9	6.9	6.4	6.6	6.3	6.7	7.4	5.7	7.3	5.8	7.8	7.7	5.1	6.0	6.0	7.8
Soil depth (cm)	40	40	26	12	16	13	4	6	4	4	5	4	5	15	9	20	8	6	16	11	11	18	15	30	20	30	20	10	20	12	8	10	5	10	8	16	40	40	40	35	40	12	20	10	22	20
Litter surface cover	15	10	13	7	5	15	10	7	6	5	10	10	7	10	10	20	8	10	9	15	15	12	13	20	10	12	15	20	10	20	8	8	10	9	12	9	20	18	20	10	20	4	1	2	4	20
No. of species	28	34	44	41	35	38	40	40	37	39	36	33	30	28	42	30	29	32	36	53	42	41	32	26	34	37	35	34	31	21	18	23	31	36	27	19	46	48	38	35	40	22	24	25	22	41
Site	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D
Echinopsio schoenii-Proustietea cuneifoliae; Echinopsio schoenii-Proustietalia cuneifoliae; Salvion oppositiflorae																																														
Junellia arequipense	2	2		2	2	2	2	2					2	2	2		2	2	3	2	2		3	3	3	3	3	3		2	4	4	3	2	3	4	2	2	2	2	2					
Proustia cuneifolia	3	3	3	3	3	3	3	3	2		2	2	2	2		3				3	3	4		2	2	2							2	2	2	2	3	3	3	3	3	2	3	2	2	
Echinopsis schoenii		3	2						2	2	2	2	2			4			2	2		3				3			2			2				2	2	2	2	2	3					
Sarcostemma solanoides	1	2	1	2	2	2	2	3	2	3	2	3	2	3	2	2		2	3	1	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	3	2	2	2	2		2	2	2	
Salvia oppositiflora	3	3	3	2	2	2	2		2	2	2	2	3		3				3	3	2	2	2	2	2	2	2	2	2	2			2	2	2	1	2	2	2	1	2					
Cumulopuntia unguispina	2	3	2	2	3	2	2	2	2	2	3	2	2	3	2	2	2	2	2		2	2	2		2	2		4	2	2	2	2	2	3	2	2	2	2	2	2	2	3	3	2	3	2
Galinsoga mandonii	2	2	2	2	2	3	2	2	2	2	2	1	2	2	2					2	2	1						2	2								1	2	2	2	1		2	2		2
Villanova oppositifolia	2	2	2	2	1				2	2		2	2		2	2	2	2	2	2	2	1	1		1	1		2	2	1												2				
Senecio tovari	2	2					2	2		2			2	1		2			2	2	2	2	2	2		2	2		2		3	3	3	3	3		3	3	3	3	3	2	2	2	2	
Bowlesia sodiroana	2	2	2	2	2	2	3	2	2	1	2		1	2																							1	1		2	1					
Oxalis megalorrhiza				2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2		2	2	2	2	1	2	2	2	2	1
Viguiera lanceolata	3	2	3	3	3			3	2	2	2	3	2	2	2				2	2	3	2	2	2	2	2	2	2	2	2								2	2							
Heliotropium microstachyum	2	2	2	2	2												1	2	2				2														2	2	2	2	2	1	1	2	2	
Lycianthes lycioides									2	2	1		2		2				3	2	2		2			2	2	2		2		2	2	2			2	2	2	2	2		2	1		
Lophopappus foliosus									3	3	3	3	3				4	3	3				3	3	2	3	4	3	3	3							2	2			2		2	2		
Gochnatia arequipensis																			3				3	3	3	3	4	3		4	3	4	4	3	4			2	3							
Cheilanthes myriophylla															2	3				2	2	2	2							1			1	2	1			1	2							
Peperomia scutaleifolia						2	2	2		2	2	2			2		2	2	1					1	2			2															1			
Cylindropuntia rosea			3	2																			2							3	3	2	2	2	2		2	2	2	2	2	4	3	3	2	2
Echeveria peruviana									2	2	2													2	2																	2	2	2		
Aa mathewsii		1	2																								1	1														2				
Paronychia setigera						2	2	2						1	2	2				2	2	1		2	2	2	1																			
Salpichroa tristis															1	2	2	2	2	2	2	2	1																							
Adesmia miraflorensis			2	2													1	2	2	2			1				1	2	2													3	3	3	2	2
Neowerdermannia peruviana						2		2																	2	2	2	2						2	2	2										
Hypochaeris chillensis			2		2										2				2	2																	2	2	2							
Mirabilis expansa			1	2	2	2	2	1																									1	2	1		2	2		2	2					
Dalea cylindrica									2		2	2	3																													2	3	2	2	
Ligaria cuneifolia											2					2				2														2				2								2
Chenopodium incisum															2	2				2	2	2															2	1			1					
Portulaca pilosa																																	1	2	2	2	2	2	2		1	2			2	
Assoc. 1. Senecioni arnaldii-Exhalimolobetum weddellii																																														
Puya ferruginea	2	2	2	2	2	3	3	3	3	2	3	3	3	3	2	2									3																					
Senecio arnaldii	2	1	2	2	3	1	2		2	2	2		2	2	1	2																														
Gamochaeta humilis	2		2			2		2				1	1																																	
Nama dichotoma	1	1	1			1			1						1																															
Exhalimolobos weddellii			2	2										2	2																															
Cryptantha peruviana	2	2	2		2																																									
Tephrocactus verschaffeltii			2	3																																										
Solanum excisirhombeum						1	2																																							
Stenomesson sp. (#2107)							1	1																																						
Gnaphalium lacteum				2																																										
Assoc. 2. Mostacillastro gracile-Chuquigaretum rotundifoliae																																														
Chuquiraga rotundifolia																	3	3	3	2	2	2	2	2	1	2	2	2	3																	
Mostacillastrum gracile																		1		1	1	1	1			2	2			1							2	1	2		1					
Caiophora cirsiifolia																1				2	3	2	2		2	2	2																			
Conyza sumatrensis var. *leiotheca*			2		2												2	2	1					2	2				2																	
Subassoc. 2.1. phacelietosum pinnatifidae																																														
Phacelia pinnatifida																	2	2	1																											
Subassoc. 2.2. chuquiragetosum rotundifoliae = subass. typicum																																														
Ipomoea minuta																2				1	1	2																								
Plazia daphnoides															2					2																										
Subassoc. 2.3. chaptalietosum similis																																														
Chaptalia similis																								1	2	2	1	2														2			1	1
Stipa obtusa																								2	2	2	2	2	2					2			2	2	2							
Sisyrinchium bracteosum																							2																							
Aristeguieta ballii																													2																	
Assoc. 3. Anredero diffusae-Diplostephietum meyenii																																														
Subassoc. 3.1. diplostephietosum meyenii = subass. typicum																																														
Anredera diffusa																														1	2	1	2	1	2	2	1	2	2	1	2					
Diplostephium meyenii																										3	2	2			2		2	2	3	3	3	3		3	3					
Subassoc. 3.2. bomaretosum ovatae																																														
Fuertesimalva echinata																															1			1			2	2	2	3	2					
Bomarea ovata																																					2	2		2	3					
Dunalia spinosa																3																					2	2		3	2					
Zephyranthes boliviana																																	1				1		1		1					
Geranium core-core																																								2						
Sedum reniforme																																							2	2						
Variant 3.2. *Calceolaria pisacomensis*																																														
Sycios baderoa																																			1		2	2			1					
Calceolaria pisacomensis																																					1	2								
4. Community of *Cylindropuntia rosea* and *Helogyne apaloidea*																																														
Helogyne apaloidea																																										2	2	3	3	
Tarasa urbaniana																																										2	1	2	2	
Nicotiana rustica																																										2			2	
5. Community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*																																														
Escallonia myrtilloides																																														4
Festuca dolichophylla																																														3
Belloa longifolia																																														2
Bomarea involucrosa					1																																									2
Gomphrena meyeniana																																														2
Ophryosporus heptantus																				2																										2
Plantago tubulosa																																														2
Tarasa tenuis																																														2
Baccharis tricuneata																																														1
Mancoa hispida																																														1
Oenothera multicaulis																																														1
Oenothera sp. (#2160a)																																														1
CS Opuntietea sphaericae																																														
Ephedra americana						2	2	2									2	2	2	2				2	2	2	2	2	2								2	2			2					
Oreocereus leucotrichus																																					3	3								
CS Polypodio-Tillandsietea																																														
Tillandsia capillaris			2	2					3	3		3	3	2		2	2	2	2	2	2	2	3	3	3	3	3	3		2	2		1	2	3		2	2					2	2		2
Tillandsia usneoides																						2														2										

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
CS Notholaenetea niveae																																														
Notholaena nivea			1	2	1		2	2	2	2		2	2	1	1		2	2	2	2	2	1	2	2	2	2	2	2		1	2	2	2	1	2	1	2	2	1							
Cheilanthes pruinata	3	3	3	3	2	3	3	3	1	2	2	2	1	3	3	3				3	2	2									2	2	2	2	2	2	2	2	2	1	1					2
Cheilanthes scariosa																1				1	1	1			2	2				2																
Woodsia monteviensis																1				1	2	2																								
Cystopteris fragilis																	2																													
CS Lantano-Chusquetea																																														
Mutisia acuminata var. *hirsuta*							2	2	3	2	1													2	2	1											3	2	2		4					
Austrocylindropuntia subulata																																2					3	2		3	3					
CS Crassuletea connatae																																														
Crassula connata				1	1																																									
CS Muhlenbergietea peruvianae																																														
Chondrosum simplex				2	2	3	2	3	3	2	2	2	2			2				1	2	2									2	2	2	2			2	2	2	2	2	2	2	1	2	1
Muhlenbergia peruviana	2	2	2	2	2		2	2						2																							2	1		2	2	3	2	2	2	
Tarasa tarapacana	2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2	1	1	2	1	2	2	1	1	2	1	1	2	1																	
Tagetes multiflora	2	1	3	2	1	1	2	2		2	2	1		1	2	2	2	1	1	2	1	2	2		1	1		2	1			1	1	2	1		2	2	2	2	2	2	2	2	2	1
CS Baccharidetea latifoliae																																														
Satureja boliviana															2					2		2																								
CS Calamagrostietea vicunarum																																														
Tunilla soehrensii		2	2	2																						2	2	3	2																	
Lophopappus tarapacanus		2	2	3		2	2	3						2	3	3				3	3	3					2	2	2															2	2	
Quinchamalium procumbens						1	1	1							1		1	1	1	1						1	1		1	1													1	2	2	1
Chersodoma jodopappa																	2	2	1																											
Luzula racemosa									2				2		2					2	1																									
Basal community																																														
Stipa ichu	2	2	2	2	2	3	2	2	2	3	2	2	2	2	2	2	4	3	2	2	3	2	3	2	3	3	2	4	2	3		2	2	2	2	2	2	3	2	3	2					3
Nassella inconspicua						2	2								2	3		2	2	2		2	2							2	2	2	2	2	2	3							2	1		
Nassella asplundii	1	2	2				3	2		2		2		2																																
Companions																																														
Stevia macbridei	2	3	3	3	2	2	3	3	3	3	3	3	3	2										2	2	2	1	2	1		1	2	2	2												2
Bidens andicola		2	3	2		2	3		1	2	2	2			3		2	1	1	2	2	2				2	2	2	2		2	1	1	1				1	2				3			2
Eragrostis nigricans		3	3	3	2	3	2		2	2	2	2	2		2	3				2	2	2									2	2	2	2								3		2	2	2
Cyperus seslerioides				2	2	2	2	2						2																		1	2	2	1		2	2	2							
Calceolaria inamoena								2	3	3	2			3		3	2	2	2	2	2	2	2										2	2												
Erigeron pazensis		2																2		1									1																	
Lobivia pampana			2	2											2				2	2	2		2	2	2								2	2	2	2										1
Valeriana radicata	3	2	2														2	2	2				2		1	2	2																			
Achyrocline ramosissima		2	2	1		2	2	2						1													1	2	2																	
Aristida adscencionis															1	2				2	2	2																								
Galium corymbosum									1	1	1				2		2	2		1	2	1	2					2	1								2		1	1	1					2
Hieracium streptochaetum						2	2	1							2					2																										
Pellaea ternifolia			1	1											2					2	2	1												1	1	1	1	1	1		1					
Poa candamoana									2	2		2	2																																	2
Nothoscordum fictile				2	2			2		2	2	2																																		2
Spergularia fasiculata						2	2	2	2	2	2														1	2	2	1	2				2	1	2	2										1
Facelis plumosa	2		2		1	2		2						2																							2	2	2							
Asplenium peruvianum															2					1																										
Chenopodium petiolare				1	1																						1	1											2	2	1					
Lupinus paruroensis						3	2	2																																						
Cardionema ramosissimum															2					2	2	1																								
Mutisia orbignyana																				2	2	2		2	2																					2
Perezia pungens																	2	3	2		2		2		2		2		2																	
Olsynium junceum																	3	3	2				2			2	2	2	2																	
Bromus catharticus																				1	2	2																								
Oxalis moqueguensis							1	1	1			1												1		1														1						
Bartsia peruviana																	1	1	1																											
Belloa piptolepis																	2	1																												
Native weeds, invasive																																														
Nothoscordum andicola			2	2	2				2	2	2																			1				1												
Ullucus tuberosus subsp. *aborigineus*	2	2																																												
Chamaecyse serpens	2	2						1	2	2	2	2	1	1																	1	1	1	1	1		2	2	2	2	2	2		2	1	
Tagetes filifolia											2																																			
Trifolium amabile			1	2	2				2	2	3																																			
Cyclospermum leptophyllum						1				1		2	1		1																															
Daucus montanus									1	1	1				1					1	1	1															1	2	1	1	1					
Tagetes minuta																																				1										
Chenopodium ambrosioides																																								1	2					
Solanum tuberosum			2																																											1
Equisetum bogotense																																														2
Juncus ebracteatus																																														2
Exotic species																																														
Galium aparine						1	2	2																																						
Medicago lupulina										3		1																																		2
Erodium cicutarium						2	2				2	1																									2		2	2	1	2	2	1	2	2
Kikuyuochloa clandestina												2																																		2
Taraxacum officinale					2																																									
Rumex crispus	2	2																																												
Sonchus oleraceus															1																															1
Solanum nigrum																													2																	
Capsella bursa-pastoris																																1								1						

Galinsoga mandonii, Gochnatia arequipensis, Heliotropium microstachyum, Hypochaeris chillensis, Ligaria cuneifolia, Lophopappus foliosus, Lycianthes lycioides, Mirabilis expansa, Junellia arequipense, Neowerdermannia peruviana, Cylindropuntia rosea, Oxalis megalorrhiza, Paronychia setigera, Peperomia scutaleifolia[7], *Portulaca perennis, Proustia cuneifolia, Salpichroa tristis, Salvia oppositiflora, Sarcostemma solanoides, Senecio tovari, Villanova oppositifolia* and *Viguiera lanceolata.* In most of the communities *Stipa ichu* bunch grass is present.

Ecology and distribution: Communities belonging to this class can be found in the valleys of the upper Tambo river in Moquegua. Judging from our relevés, the vegetation of this class is distributed from 3470 m on the slopes of Toreqaqa in Exchaje to 3700 m in Arapa-Yunga. It is assumed that the class distribution ranges from 16°16' S, 70°45'W (Yalagua) to 16°08'S, 70°37'W (Antajahua) between 3200 and 3700 m where the high cover and frequency of *Echinopsis schoenii* and *Cylindropuntia rosea* typically occurs in

7 The especies was later identified as *Peperomia scutaleifolia* (A. Pauca 2015, pers. comm., 25 March).

association with the shrubs *Junellia arequipense, Proustia cuneifolia* and herbs (*Galinsoga mandonii, Sarcostemma solanoides, Oxalis megalorrhiza,* among others) that are typical of the landscape in this region. In general, the Andean scrub vegetation extends over large areas in the Andes of Peru and Bolivia, and probably the north of Chile (Galán de Mera et al. 2003; Navarro 1993). Our descriptions have similarities with those made by Galán de Mera et al. (2003), but differ markedly in character species and general composition.

Echinopsio schoenii-Proustietalia cuneifoliae Montesinos, Cleef & Sýkora 2012
Syntype: *Salvion oppositiflorae* Montesinos, Cleef & Sýkora 2012
Salvion oppositiflorae Montesinos, Cleef & Sýkora 2012
Typus: *Senecioni arnaldii-Exhalimolobetum weddellii* Montesinos, Cleef & Sýkora 2012
Table 4.
Physiognomy and composition: The shrubland communities of this alliance consist of vegetation layers composed of several Cactaceae species, other succulents, hemiparasites, rock ferns and spiny shrubs. The ground layer is dominated by several herbs, mosses and ferns. These communities occur along Andean slopes from the south of Peru, in the dry ravines that have been cut into pumice deposits.
Syntaxonomy: In our study within this alliance we distinguished 3 associations from eight sites on the Andean slopes of Moquegua.
Ecology and distribution: The vegetation of this alliance was found at an altitude ranging between 3470 and 3700 m in the areas adjacent to the villages of Exchaje, Camata, Yunga, Pampilla, Arapa and Sefincane (Ubinas, Ichuña and Yunga Districts). It also occurs in limited areas of the Andean valleys of Arequipa, Moquegua and Tacna where *Salvia oppositiflora* may be found.

1. *Senecioni arnaldii-Exhalimolobetum weddellii* Montesinos, Cleef & Sýkora 2012
Typus: Rel. No. 3 (Montesinos YSE3). Table 4. Photo 1, 2.
Physiognomy and composition: The Andean shrublands of *Senecio arnaldii* and *Exhalimolobos weddellii* are characterised by the relative high abundance of *Senecio arnaldii* developing on rocky slopes with low shrubs, herbs and bunch grasses. The layer of the spiny ground rosette *Puya ferruginea* (with brownish-green tubular flowers) and the endemic *Senecio arnaldii* (1 m) attains 15–25% of the total cover. The shrub *Junellia arequipense* is common where tall shrubs (1–1.5 m) of *Proustia cuneifolia are* predominant and *Salvia oppositiflora* (60–80 cm) also occurs.
Syntaxonomy: The association comprises 102 species occurring in 16 relevés. Diagnostic species are: *Stenomesson* sp. (# 2107), *Cryptantha peruviana, Tephrocactus verschaffeltii*[8], *Exhalimolobos weddellii, Gamochaeta humilis, Gnaphalium lacteum, Nama dichotoma, Puya ferruginea, Senecio arnaldii, Solanum excisirhombeum.* Other species characteristic of this association include: *Facelis plumosa, Nothoscordum fictile, Oxalis moqueguensis*[9],

8 The unknown species of *Cumulopuntia* was later identified as *Tephrocactus verschaffeltii* (Hoxey 2014).
9 The unknown species was later identified as *Oxalis moqueguensis* (Montesinos-Tubée 2015b).

Poa candamoana. Species with relatively high frequency: *Cheilanthes pruinata, Oxalis megalorrhiza, Stipa ichu* and the annual herb *Tagetes multiflora*.

Ecology and distribution: The Andean shrub vegetation of the association *Senecioni arnaldii-Exhalimolobetum weddellii* can be found on the the north-facing slopes of the Tambo river valley northern slope of the Tambo River (nearby the confluence with the river Sefincane) in the sectors of Arapa, Jatuntio and Sefincane, between 3560 and 3700 m. Vegetation cover 78%.

2. ***Mostacillastro gracile-Chuquiragetum rotundifoliae*** Montesinos, Cleef & Sýkora 2012

Typus: Rel. No. 20 (Montesinos QFP2). Table 4. Photo 2.

Physiognomy and composition: This association is characterised by a high cover The following shrubs are characteristic: *Calceolaria inamoena, Gochnatia arequipensis, Junellia arequipense, Lophopappus foliosus, Mutisia acuminata, Mutisia orbignyana, Lophopappus tarapacanus*[10].

The community is commonly composed of the shrub *Junellia arequipense,* the dwarf shrub *Mostacillastrum gracile* and the herbs *Chaptalia similis, Olsynium junceum, Perezia pungens, Valeriana radicata*[11], the vine *Caiophora cirsiifolia* and grasses such as *Stipa obtusa, Chondrosum simplex, Poa candamoana* and *Stipa ichu.* is also common; with aromatic inflorescences. The ferns *Cheilanthes pruinata, Cheilanthes myriophylla, Cheilanthes scariosa, Notholaena nivea*[12] commonly grow in rock crevices. Cacti such as *Cumulopuntia unguispina*[13], *Neowerdermannia peruviana* and *Tunilla soehrensii* have a significant presence. The occasional occurrence of the orchid *Aa mathewsii,* the aromatic woody shrub *Aristeguietia ballii,* the resinous *Plazia daphnoides* and the pink-flowering *Sisyrinchium bracteosum* are characteristic.

Syntaxonomy: This association is based on 13 relevés with 86 species grouped in 77 genera and 35 families. The diagnostic species are *Caiophora cirsiifolia, Chuquiraga rotundifolia, Conyza sumatrensis* var. *leiotheca, Mostacillastrum gracile, Perezia pungens* and *Olsynium junceum*. Three subassociations were recognised: *phacelietosum pinnatifidae, chuquiragetosum rotundifoliae* (subass. *typicum*) and *chaptalietosum similis.*

Ecology and distribution: The lower Andean shrubland of the association Mostacillastro gracile-Chuquiragetum rotundifoliae can be found on the mountain slopes close to the Tambo river streams near town Pampilla, between 3570–3700 m. The species *Chuquiraga rotundifolia* is present in the Andes of Peru (Brako & Zarucchi 1993) and Chile (Luebert & Gajardo 2005). Luebert & Gajardo (2005) determined the association of the species together with *Polylepis* trees

10 The name was modified to *Lophopappus tarapacanus* displacing *Proustia berberidifolia* according to Katinas et al. (2013), (A. Granda 2015, pers. comm., 25 June).

11 The especies was later identified as *Valeriana radicata*. The taxon *Valeriana interrupta* grows at higher altitudes (Montesinos-Tubée 2015b).

12 Published as *Argyrochosma nivea* and *Argyrochosmetea niveae* for the chasmophyte class level in Montesinos-Tubée et al. (2015b).

13 The especies was later identidied as *Cumulopuntia unguispina*, the name *Opuntia corotilla* is currently under discussion to determine its taxonomic position (A. Pauca 2015, pers. comm., 25 March).

in northern Chile and it was confirmed by Galán de Mera et al. (2003). In our study area *Polylepis* species are absent; we found the association of the spiny *Chuquiraga* growing on undisturbed terrain with numerous native species and differentiated it from the association described by Luebert & Gajardo (2005) because of its composition and geographical distribution.

2. *Mostacillastro gracile-Chuquiragetum rotundifoliae* Montesinos, Cleef & Sýkora 2012
2.1 *phacelietosum pinnatifidae* Montesinos, Cleef & Sýkora 2012
Typus: Rel. No. 18 (Montesinos QFY2). Table 4.
Physiognomy and composition: The shrubs have a dense cover and attain a height of 1–1.5 m. For further description see the association; other species abundant in this association are *Calceolaria inamoena, Cumulopuntia unguispina, Echinopsis schoenii, Junellia arequipense, Notholaena nivea, Stipa ichu, Tarasa tarapacana* and *Valeriana radicata*. The layers differ from those of the association because of the major presence of *Chuquiraga rotundifolia* (10–20%), *Lophopappus foliosus* (10–20%) and *Stipa ichu* (15–18%). *Adesmia miraflorensis, Heliotrophium microstachyum, Olsynium junceum* and *Peperomia peruviana* are also present.
Syntaxonomy: The subassociation is defined on the basis of three relevés with a composition of 41 species. The diagnostic species of this subassociation is *Phacelia pinnatifida*; *Bartsia peruviana* and *Belloa piptolepis* are also abundant.
Ecology and distribution: The shrub vegetation of the subassociation *phacelietosum pinnatifidae* is located between 3630 and 3660 m, on the slopes along the path running between the towns of Tassa and Camata, northwest of Pampilla town. On slopes with abundant rocks and bare soil the vegetation cover is only 60%. The diagnostic species *Phacelia pinnatifida is* restricted to this habitat.

2. *Mostacillastro gracile-Chuquiragetum rotundifoliae* Montesinos, Cleef & Sýkora 2012
2.2 *chuquiragetosum rotundifoliae* Montesinos, Cleef & Sýkora 2012 = subass. *typicum* Typus: Rel. No. 20 (Montesinos QFP2). Table 4.
Physiognomy and composition: As for the association, but with characteristic higher abundance of *Caiophora cirsiifolia, Salvia oppositiflora* and *Viguiera lanceolata* within the stands of *Chuquiraga rotundifolia.* It is differentiated from the *phacelietosum pinnatifidae* by the presence of *Cheilanthes myriophylla, Cheilanthes pruinata, Cheilanthes scariosa, Chenopodium incisum, Eragrostis nigricans, Paronychia setigera, Pellaea ternifolia, Proustia berberidifolia, Proustia cuneifolia* and *Satureja boliviana.* The higher abundance of *Proustia berberidifolia* and *Proustia cuneifolia* (10–20% cover) are characteristic.
Syntaxonomy: The subassociation typicum is defined by a total of 56 species. The presence of *Ipomoea minuta* and *Plazia daphnoides* are diagnostic and absent in other communities.

Ecology and distribution: The shrublands of the subassociation *typicum* are located between 3570 and 3580 m, on the slopes along the path between the towns of Tassa and Camata, north of the town of Pampilla. The shrub community has a high cover (75%).

2. *Mostacillastro gracile-Chuquiragetum rotundifoliae* Montesinos, Cleef & Sýkora 2012

2.3 *chaptalietosum similis* subass. nov.

Typus: Rel. No. 26 (Montesinos PCH3). Table 4.

Physiognomy and composition: The shrub layer on the slopes is 60–140 cm tall. *Adesmia miraflorensis, Diplostephium meyenii, Gochnatia arequipensis, Junellia arequipense, Lophopappus foliosus, Lycianthes lycioides, Mutisia orbignyana, Salvia oppositiflora, Stevia macbridei, Viguiera lanceolata* are important in the shrub layer. Species in the ground layer with a relatively high cover include *Bidens andicola, Oxalis megalorrhiza, Paronychia setigera, Perezia pungens, Tagetes multiflora, Tarasa tarapacana, Valeriana radicata* and *Villanova oppositifolia* and the climbers *Caiophora cirsiifolia* and *Sarcostemma solanoides.* Characteristic is the presence of *Achyrocline ramosissima, Echeveria peruviana, Mutisia acuminata, Neowerdermannia peruviana, Spergularia fasiculata* and *Tunilla soehrensii*.

Syntaxonomy: The subassociation of *chaptalietosum similis* is defined on the basis of seven relevés with 61 species.

The diagnostic species in the shrubland include *Aristeguietia ballii, Chaptalia similis, Sisyrinchium bracteosum* and *Stipa obtusa.* The relative high abundance for *Neowerdermannia peruviana* is also characteristic.

Ecology and distribution: The Andean shrub vegetation of the subassociation *chaptalietosum similis* is of medium stature and density. On the slopes between 3610 and 3700 m the cover is relatively high (60–80%) at Chojo (north of Pampilla) and Yanaqaqa (west of Pampilla).

3. *Anredero diffusae-Diplostephietum meyenii* Montesinos, Cleef & Sýkora 2012

Typus: Rel. No. 34 (Montesinos CAY4). Table 4. Photo 3, 4.

Physiognomy and composition: These Andean shrublands have a taller and denser cover of succulents with a varied canopy, combined with a high density of spiny shrubs, Cactaceae, ferns, grasses and annual herbs. On these sites cacti species have the highest cover and diversity of all the communities described in this paper.

The shrub layer is 1 to 3 m tall and also contains also erect cacti (*Echinopsis schoenii*) that can be up to 4 m tall. Shrubs include *Diplostephium meyenii, Dunalia spinosa, Gochnatia arequipensis, Junellia arequipense, Lycianthes lycioides, Mutisia acuminata, Proustia cuneifolia* and *Senecio tovari.* Several cacti species are also abundant with varying cover: *Austrocylindropuntia subulata*[14], *Oreocereus leucotrichus, Cumulopuntia unguispina, Cylindropuntia rosea, Lobivia pampana*[15], *Echinopsis schoenii* and *Neowerdermannia*

14 The species name was uipdated to *Austrocylindropuntia subulata* (Montesinos-Tubee 2015b).

15 The species was updated to *Lobivia pampana* (Ostolaza 2014).

peruviana. The grasses *Stipa obtusa, Chondrosum simplex, Eragrostis nigricans, Nassella inconspicua* and *Stipa ichu* are present. The succulent *Anredera diffusa* commonly grows as a climber close to the erect stems of the shrubs. *Tillandsia usneoides* (very well distributed in rocky rifts along the river basin) grows on the columnar stems of *Echinopsis schoenii* as seen in relevé 36. This community is probably the most representative of the vegetation series of this class.

Syntaxonomy: This association is based on 12 (5 × 5, 6 × 6 m) relevés with 70 species. Diagnostic species are *Anredera diffusa, Austrocylindropuntia subulata, Diplostephium meyenii, Fuertesimalva echinata, Sicyos baderoa* and *Zephyranthes boliviana.*

Within the *Anredero diffusae-Diplostephietum meyenii* we distinguished the subassociations *bomaretosum ovatae* and the variant of *Calceolaria pisacomensis.*

Ecology and distribution: The association of *Anredero diffusae-Diplostephietum meyenii* comprises the Andean shrublands occurring at the lowest altitude of the present study (3470 m). The communities are located between 3470 and 3650 m on the mountain slopes surrounding the Tambo river basin at the sites of Toreqaqa, south of Exchaje town, the site of Yanarico (on sites with ancient ruins of past civilizations) south of Camata town and one relevé from the slope near the town of Pampilla. The sites belonging to this association are characterised by a soil texture with abundant loose stones.

3. *Anredero diffusae-Diplostephietum meyenii* Montesinos, Cleef & Sýkora 2012

3.1 *diplostephietosum meyenii* Montesinos, Cleef & Sýkora 2012 = subass. *typicum*

Typus: Rel. No. 34 (Montesinos CAY4). Table 4. Photo 4.

Physiognomy and composition: Open and dense vegetation with cacti and shrub vegetation dominated with small clustered cacti of *Cylindropuntia rosea* and *Cumulopuntia unguispina* with a relative high cover. The shrubs are dominated by *Junellia arequipense, Senecio tovari, Gochnatia arequipensis* and *Diplostephium meyenii* (30–50% cover). The ground layer is dominated by annual herbs of *Oxalis megalorrhiza* and *Anredera diffusa,* the ferns *Notholaena nivea* and *Cheilanthes myriophylla.*

Syntaxonomy: The subassociation typicum of the *Anredero diffusae-Diplostephietum meyenii* is represented by 7 relevés, with 48 vascular species. *Anredera diffusa* and *Diplostephium meyenii* are diagnostic. This subassociation typicum is separated from the subassociation *bomaretosum ovatae* by the absence of *Bomarea ovata* and *Dunalia spinosa,* a very low presence of *Fuertesimalva echinata* and *Zephyranthes boliviana,* and by a greater density and cover of *Junellia arequipense* and *Gochnatia arequipensis.*

Ecology and distribution: The vegetation of the subassociation *typicum* covers the eastern slopes (Yanarico site) of the Tambo river at 3520–3650 m. This side of the slopes is drier than the western slopes where the subassociation bomaretosum ovatae occurs.

3. *Anredero diffusae-Diplostephietum meyenii* Montesinos, Cleef & Sýkora 2012
3.2 *bomaretosum ovatae* Montesinos, Cleef & Sýkora 2012
Typus: Rel. No. 40 (Montesinos EXC1). Table 4.
Physiognomy and composition: Dense shrub and columnar cacti vegetation with annual herbs and grasses. The appearance is a layer of shrubs 1–3 m tall, with 30–50% cover, and a layer of columnar cacti up to 3–5 m with 4 to 6% cover.
Among the shrubs are *Diplostephium meyenii, Gochnatia arequipensis, Junellia arequipense, Lycianthes lycioides, Mutisia acuminata, Proustia cuneifolia, Salvia oppositiflora, Senecio tovari*. The relatively higher abundance of *Diplostephium meyenii, Dunalia spinosa, Mutisia acuminata* and *Proustia cuneifolia* and the dwarf shrub *Mostacillastrum gracile* are characteristic. The herb layer includes several annual species; the most frequent are *Bowlesia sodiroana, Chenopodium petiolare, Fuertesimalva echinata, Galinsoga mandonii, Galium corymbosum, Heliotropium microstachyum, Hypochaeris chillensis, Sarcostemma solanoides, Tagetes multiflora* and grasses such as *Stipa obtusa, Chondrosum simplex, Muhlenbergia peruviana, Stipa ichu.* Ferns growing in rock crevices, and columnar and clustered cacti are also characteristic of this vegetation.
Syntaxonomy: The subassociation is represented by five (5 × 5 m) relevés with a total of 57 species. Diagnostic species are *Austrocylindropuntia subulata, Bomarea ovata, Oreocereus leucotrichus, Calceolaria pisacomensis, Geranium core-core*[16], *Fuertesimalva echinata, Sedum reniforme, Sicyos baderoa* and *Zephyranthes boliviana.*
Ecology and distribution: The shrubland of the subassociation *bomaretosum ovatae* is located at altitudes between 3470 and 3520 m, on the slopes at Toreqaqa (NE of the confluence with Yarihualla river). The sites attain a relatively high vegetation cover (65–75%) and have slopes of 12 to 30° with predominantly dark red alluvial soils (pH 6.8).

3. *Anredero diffusae-Diplostephietum meyenii* Montesinos, Cleef & Sýkora 2012
variant of *Calceolaria pisacomensis*
Representative relevé: Montesinos EXC4, rel. No. 38, Table 4.
Physiognomy and composition: The physiognomy and species composition correspond to those of the subassociation.
Syntaxonomy: This variant is represented by two relevés with 51 species. Diagnostic species are *Oreocereus leucotrichus* and *Calceolaria pisacomensis*.
Ecology and distribution: The variant of *Oreocereus leucotrichus* is found at altitudes of 3500 m (~3700 m), on rocky slopes with a dense cover of dwarf shrubs (especially *Senecio tovari*). *Oreocereus leucotrichus* forms large clustered groups of 10–20 m² and 20–70 cm height. The endemic red-flowered dwarf shrub *Calceolaria pisacomensis* is restricted to the variant.

16 The species was identified as *Geranium core-core* after a morphological analysis done at USM (2013).

4. Community of *Cylindropuntia rosea* and *Helogyne apaloidea*
Representative relevé: Montesinos PHU4, rel. No. 42, Table 4. Photo 5.
Physiognomy and composition: Dry open and low scrub with patches of bare ground. Rosettes and bunch grasses are almost absent. A high density of Cactaceae and annual herbs is characteristic.
The shrub layer reaches up to 100 cm in height, and the canopy consists of *Helogyne apaloidea* (4–7% cover), *Proustia cuneifolia* (3–7% cover), *Senecio tovari* (3% cover) and the sprawling dwarf shrub *Dalea cylindrica* (5% cover). Other shrub species are scarce and include *Adesmia miraflorensis, Lophopappus foliosus, Lycianthes lycioides,* and *Proustia berberidifolia.* Among other species present in this dry scrub are the climber *Sarcostemma solanoides*, the orchid *Aa mathewsii,* the succulent *Echeveria peruviana*, the epiphytic *Tillandsia capillaris* and hemiparasitic *Quinchamalium procumbens.* Annual herbs include, *Bidens andicola, Chamaesyce serpens, Erodium cicutarium, Galinsoga mandonii, Heliotrophium microstachyum, Oxalis megalorrhiza, Portulaca perennis* and *Tagetes multiflora.* Ferns are absent. Among grasses *Eragrostis nigricans, Nassella inconspicua* and *Muhlenbergia peruviana* are common. Only two species of the Cactaceae family occur with a relative high cover (*Cumulopuntia unguispina* and *Cylindropuntia rosea*).
Syntaxonomy and Composition: The community of *Cylindropuntia rosea* and *Helogyne apaloidea* is based on four relevés (30 m^2 each) with 32 vascular species. The dry scrub is distinguished by the presence of *Chaptalia similis, Helogyne apaloidea, Nicotiana rustica* and *Tarasa urbaniana* as diagnostic species. This community lacks the diagnostic species described for the alliance.
Ecology and distribution: The dry scrublands of *Cylindropuntia rosea* and *Helogyne apaloidea* are distributed on a small mountain in Huañasco, south of Pampilla town between 3580 and 3610 m. The relatively high presence of introduced herbs can be ascribed to cattle.

5. Community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*
Representative relevé: Montesinos PES1, rel. No. 46, Table 4. Photo 6.
Physiognomy and composition: Dense grass and tree vegetation dominated by *Escallonia myrtilloides* dwarf trees (between 2 and 4 m in height, 12–25 cm DBH and 30% of cover). The most important shrub species in the canopy are *Adesmia miraflorensis, Mutisia orbignyana* and *Stevia macbridei* all of which approach a height of 1 and 1.5 m and have a cover of 15%. The herb layer is composed by *Bidens andicola, Chaptalia similis, Chondrosum simplex, Eragrostis nigricans, Erodium cicutarium, Galinsoga mandonii, Galium corymbosum, Medicago lupulina, Nothoscordum fictile, Poa candamoana, Quinchamalium procumbens, Spergularia fasiculata, Stipa ichu* and *Tagetes multiflora.* The cacti *Cumulopuntia unguispina, Cylindropuntia rosea* and *Lobivia pampana* occur with 4–6% cover. *Cheilanthes pruinata* is also characteristic. The vegetation cover reaches up to 80% in these stunted forests.

Syntaxonomy: The community of *Ophryosporus heptanthus* and *Escallonia myrtilloides* is based on one relevé with 41 plant species. This community can be distinguished by the presence of the following species: *Baccharis tricuneata, Belloa longifolia, Bomarea involucrosa, Escallonia myrtilloides, Festuca dolichophylla, Gomphrena meyeniana, Mancoa hispida, Oenothera multicaulis, Ophryosporus heptanthus* and *Tarasa tenuis.* The herb layer is also characterised also by the presence of the introduced and occasional species *Equisetum bogotense, Pennisetum clandestinum, Juncus ebracteatus, Plantago tubulosa, Solanum tuberosum, Sonchus oleraceus,* which occur on these slopes of humid soils and close to grasslands commonly grazed by alpacas, llamas and sheep. We consider this community to be independent of the class described in this paper.
Ecology and distribution: This plant community occurs at 3700 m. It is reported from the site of Sicunaya near the town of Pampilla (Yunga District). After Mueller-Dombois & Ellenberg (1974), these forest patches could be defined as discontinous scrubs.

In Figure 3, a profile diagram was built to identify the difference in structure and physiognomy of the associations and communities here described.

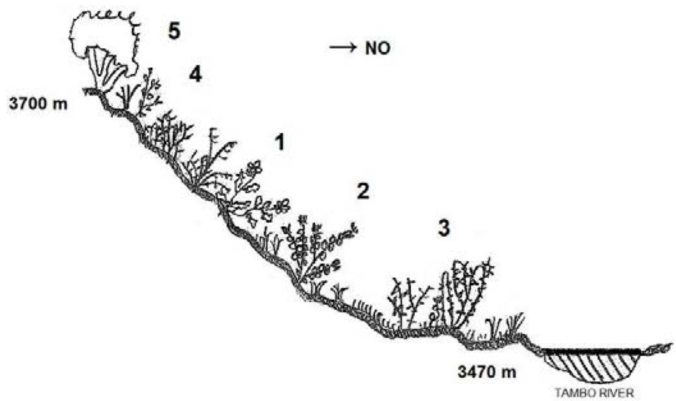

Figure 3. Profile diagram of the Prepuna shrublands of Moquegua (Peru): 1. *Senecioni arnaldii-Exhalimolobetum weddellii*, 2. *Mostacillastro gracile-Chuquiragetum rotundifoliae*, 3. *Anredero diffusae-Diplostephietum meyenii*, 4. Community of *Cylindropuntia rosea* and *Helogyne apaloidea* and 5. Community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*.

Photo 1. Prepuna with spiny shrubs and annual herbs (*Senecioni arnaldii-Exhalimolobetum weddellii*). Arapa site (Rel. 7) 3690 meters, Moquegua, Peru.

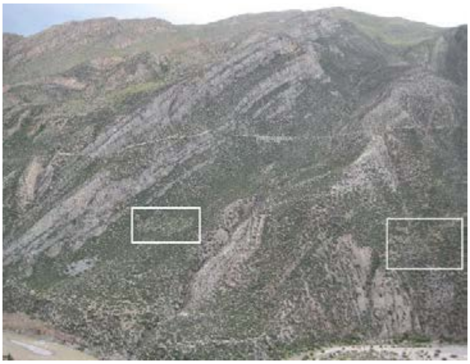

Photo 2. General view of the *Senecioni arnaldii-Exhalimolobetum weddellii* (marked in squares) from the class *Echinopsio schoenii-Proustietea cuneifoliae* occurring in Moquegua, Peru.

Photo 3. Relevé 40 (EXC1) with a dense scrub and Cactaceae vegetation corresponding to the *Anredero diffusae-Diplostephietum meyenii*. Toreqaqa slopes, south of Exchaje town, 3470 m.

Photo 4. Slope where *Mostacillastro gracile-Chuquiragetum rotundifoliae* occurs at 3660 m on Qaqahuara Mountain.

Photo 5. Community of *Cylindropuntia rosea* and *Helogyne apaloidea* with occasional presence of livestock. Huañasco site, 3580 m.

Photo 6. Forest patches of *Escallonia myrtilloides* with *Bomarea involucrosa* occurring on heavily grazed grasslands on humid slopes.

Environmental relation analysis (DCA)

The main variation in vegetation composition (axis 1) is mainly related to pH, % rocks (r^2 20 and 33), altitude (r^2 24) and inclination (r^2 32). The second axis is mainly related to altitude (r^2 20) and litter surface cover (r^2 25) and less also to dung (r^2 11), percentage of inclination (r^2 12) and soil depth (r^2 10). All other variables have lower coefficients of determination.

According to the DCA diagram (Fig 4), the first axis is mostly correlated to rock percentage and slope, followed by altitude and pH (negative relationship). This means that slope angle, rocks, altitude and higher pH are significantly related to species composition in the Prepuna vegetation, and appears more important than other variables such as soil depth, litter surface cover, stone percentage, grazing, charcoal and vegetation cover. The ordination diagram of the first DCA axis compared to the second DCA axis with the samples (relevés) shows a fairly separation of vegetation communities established on the phytosociological table (table 4). *Senecioni arnaldii-Exhalimolobetum weddellii, Mostacillastro gracile-Chuquiragetum rotundifoliae* and the community of *Cylindropuntia rosea* and *Helogyne apaloidea*, are separated from *Anredero diffusae-Diplostephietum meyenii*, suggesting that these vegtypes are associated with higher slope angles and rock cover. The *Anredero diffusae-Diplostephietum meyenii* is positevely correlated to manure percentage, deeper soils, litter surface cover and stone percentage cover and negatively correlated to altitude and slope angle.

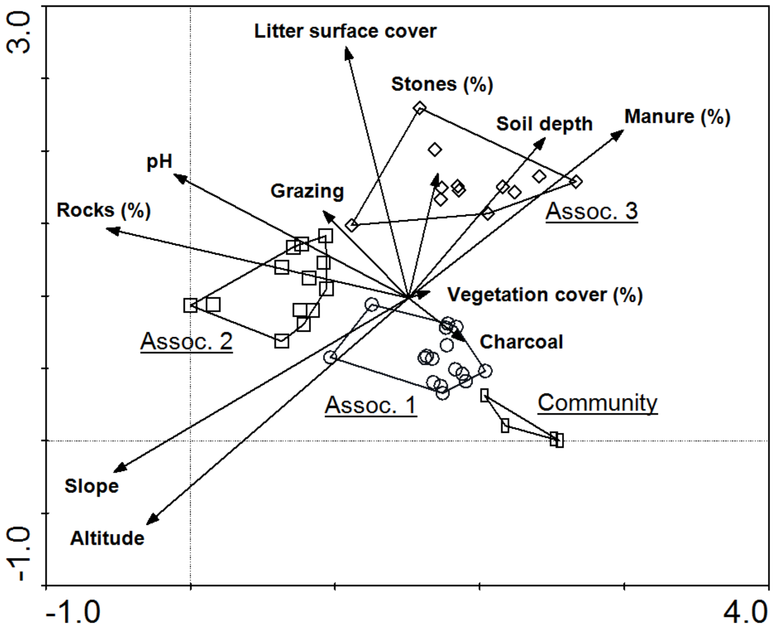

Figure 4. Ordination diagram (DCA) showing the relation with 11 environmental variables with 3 associations and 1 community. Envelopes for association (1): *Senecioni arnaldii-Exhalimolobetum weddellii*; association (2): *Mostacillastro gracile-Chuquiragetum rotundifoliae*; association (3): *Anredero diffusae-Diplostephietum meyenii* and community of *Cylindropuntia rosea* and *Helogyne apaloidea*.

Discussion

Syntaxonomy

The phytosociological classification on the Prepuna vegetation of the slopes of the upper Tambo River resulted in one new class: *Echinopsio schoenii-Proustietea cuneifoliae*, one new order: *Echinopsio schoenii-Proustietalia cuneifoliae* and one new alliance: Salvion oppositiflorae. The associations, subassociations, variant and one community have been included in these higher units that correspond to the shrublands occurring at an altitudinal range of 3470 to 3700 m. The character species of the *Echinopsio schoenii-Proustietea cuneifoliae*, i.e. *Echinopsis schoenii* and *Proustia cuneifolia* are geographically restricted to the slopes of the upper Tambo river valley and the rest of species are native or endemic to the Andes of Peru (Brako & Zarucchi 1993; Arakaki & Cano 2003; Montesinos-Tubée 2011a). Their distribution is different from the species presented for the class *Opuntietea sphaericae* (Galán de Mera & Vicente Orellana 1996; Galán de Mera & Gómez Carrión 2001; Galán de Mera et al. 2002a,b; Galán de Mera 1999, 2005).

For comparison with other relevant publications and tables we made a synoptic table based on the cluster centroids of our communities and of clustercentroids or separate relevés of comparable communities as published in literature from Peru, Bolivia and Chile (Table 5).

Notably according to the floristic data and records on the geographical distribution as presented in the comparative table (presence table) suggest that only three species are actually in common, out of fifty species contained by the *Opuntietea sphaericae*. The newly described class differs in altitudinal distribution and in species composition, including in characteristic species. In contrast to the *Opuntietea sphaericae*, the units of the *Echinopsio schoenii-Proustietetea cuneifoliae* have a high cover and presence of shrubs and herbs, with few cacti species that differ from those of *Opuntietea sphaericae*. The chorology of the species of *Echinopsio schoenii-Proustietea cuneifoliae* is more similar to that of the species recorded on the upper mountain slopes of Tacna (Gobierno Regional de Tacna 2007) and La Unión, Cotahuasi (Asociación Especializada para el Desarrollo Sostenible 1998). Given the large number of characteristic and other diagnostic species in the vegetation we have described and the great difference in species composition compared with other published syntax, we propose that a new class be created. The following are high frequency species that we consider to be characteristic of our new class: *Junellia arequipense* (Galán de Mera et al. 2003, 2009), *Proustia cuneifolia* (Navarro 1993), *Sarcostemma solanoides* (Galán de Mera et al. 2009), *Salvia oppositiflora* (Gutte 1986), *Senecio tovari* (Galán de Mera et al. 2004), *Lophopappus foliosus* (Galán de Mera et al. 2003), *Gochnatia arequipensis* (Galán de Mera et al. 2009), *Aa mathewsii* (Gutte 1986) and *Dalea cylindrica* (Galán de Mera et al. 2009). They are present in other published tables in different classes and only with very low frequency, sometimes even in only one relevé, and thus cannot be considered to be characteristic of these other syntaxa (see table 5). Moreover the new class we describe contains additional diagnostic species not mentioned in the literature and presented.

The same principle applies to the inventories of the *Deuterocohnio-Puyetea ferrugineae* (Rivas-Martínez & Navarro in Navarro & Maldonado 2002), *Lantano-Chusquetea ramosissimae* (Bolos et al 1991), *Notholaenetea niveae* (Gutte 1986) and *Calamagrostietea vicunarum* (Rivas-Martínez & Tovar 1982).

The newly proposed alliance *Salvion oppositiflorae* consists of the Prepuna of the southern Peruvian highland valleys that run down to the Pacific Ocean. Floristically and ecologically this alliance is very different from the *Corryocaction brevistyli* (Galán de Mera & Vicente Orellana 1996) whose characteristic species *Junellia arequipense* and *Gochnatia arequipensis* have a very low cover (+) and frequency and occur in only a few separate relevés and at a lower altitude (2770 m). By contrast, in the communities we have described these species are very well represented. They are diagnostic to the units with *Salvia oppositiflora* (apparently only well represented in Moquegua and absent from other phytosociological studies from Peru and Bolivia).

Communities with *Puya ferruginea* typically occur on slopes that are prone to fire (started by people); even though that they are close to abandoned cropland, the presence of introduced or invasive species is common and could be related also to livestock influence. Following the species order in the table, subassociations may be formed but since these communities remain occasionally influenced by disturbance, we decided to maintain this as a single association. *Puya ferruginea* is found at altitudes between 500 and 3500 metres (Brako & Zarucchi 1993), especially in central and South Peru. We have designated the *Puya ferruginea* community in Moquegua because the diagnostic species are abundant and frequent on several mountain slopes on eroded terrains between 2500 meters. Other studies (Gutte 1986; Galán de Mera & Gómez Carrión 2001; Galán de Mera et al. 2004, 2009) include the species in other syntaxonomical units at lower altitudes that have large differences in composition. We conclude that the spiny shrub forms part of different type of ecosystems and is grows where in the south Andes of Peru where disturbance (fire) occurs, as is the case in the valleys of the upper Tambo river. The description of the new association is based on the presence of the species in 16 relevés.

When we compared our community with *Diplostephio meyenii-Fabianetum ramulosae* Luebert & Gajardo (Luebert & Gajardo 2005) from the northern Andes of Chile we found differences in vegetation composition and species affinities. We define our community to be typical of the semiarid shrublands of South Peru, which receive more rainfall than the northern Andes of Chile and thus have a richer species composition than the regions further south. This demonstrates that *Diplostephium meyenii* is not restricted to Peru (Brako & Zarucchi 1993). The community of *Diplostephio tacorensis-Parastrephietum lepidophyllae* from Galán de Mera et al. (2003) is representative for the southern Andean valleys of Peru and has been described in a broad geographical range. Several species that occur in that community are absent from ours: the Sørensen index indicates a similarity of only 17% and only 1 of the 11 characteristic species indicated in the type inventory of that community is present. Galán de Mera et al. (2003) described *Dunalio spinosae-Baccharidetum latifoliae* whose Sørensen index also indicates a 17% similarity and in which only three of the nine characteristic species indicated in the type inventory are present in our community. Greater differences can be found in the absence of shrubs and cacti species that are characteristic of our communities.

Because the alliance *Peperomio galioidis-Puyion ferrugineae* (Galán de Mera et al. 2002a) has been described from lower altitudes only (265–310 m), it does not contain many characteristic species that are present in our communities. The relevés studied by Galán de Mera et al. (2002a) were in a drier region and are characteristic of the northern Andean slopes in Arequipa (Peru).

Though the alliance *Fabianion stephanii* (Galán de Mera et al. 2003) has a number of species in common with our vegetation tables in terms of characteristic and diagnostic species and it differs greatly from the communities described in this paper. The difference is great because both the Fabianion and the communities we have described comprise many endemic species. Species shared include: *Chuquiraga rotundifolia, Mutisia orbignyana, Ophryosporus heptanthus, Junellia arequipense, Lophopappus foliosus, Mutisia acuminata, Austrocylindropuntia subulata, Proustia berberidifolia, Stipa ichu*. Only four of the diagnostic and characteristic species we have distinguished also occur but with low cover in the table of Galán de Mera et al. (2003). Using the Sörensen index to compare the type relevé with the type relevé of the new alliance yielded a similarity of only 6%. From the type relevé of the *Fabianion stephanii* only 2 species occur in the new alliance *Salvion oppositiflorae*.

We also compared our communities with other units described from the south Andes of Peru, west of Bolivia and north of Chile. Although there is overlap in companion species, our communities differ considerably in floristic composition and in the presence of characteristic species.

We also compared our results to the *Deuterocohnio longipetalae-Puyetea ferrugineae* Rivas-Martínez & Navarro in Navarro & Maldonado (2002) and *Calamagrostietea vicunarum* Gutte, 1985 and we found differences in geographical distribution and floristic composition. The grasslands of *Calamagrostietea vicunarum* Gutte 1985 that occur only above 3800 m in the Moquegua study area will be dealt with in a separate paper describing the *Puya raimondii* communities.

The class *Chondrosomo simplicis-Muhlenbergietea peruvianae* Rivas-Martínez & Navarro as described from Bolivia (Navarro & Maldonado 2002), a ruderal community, is based on the occurrence of annual and ruderal species and is found along cattle tracks and paths in the high Andes of Peru and Bolivia. Common elements of these communities are *Chondrosum simplex, Muhlenbergia peruviana, Tagetes multiflora* and *Tarasa tarapacana*. These species have a very wide distribution and are also common in various natural

stands of annual herb vegetation in the southern Andes, as they are on colluvial slopes in Moquegua.
The same applies to the class *Crassuletea connatae* (Galán de Mera 1999), which is based on *Crassula connata* and described as therophytic and pioneer vegetation from the coasts of Peru and Chile. *Crassula connata* is an annual small herb with a very wide altitudinal amplitude, as it is present in the south of Peru in almost any type of ecosystem between 0 and 4600 m (Brako & Zarucchi 1993, Montesinos-Tubée 2011a). In our study area it is a species occurring naturally on slopes with heavy rainfall and dense vegetation cover.
The shrub community of *Senecio tovari* & *Tecoma sambucifolia* (Galán de Mera et al. 2004) from the Andes of Lima (2200 m) is based on only one relevé that has only *Senecio tovari* and *Stipa ichu* in common with our communities and has been made at a lower altitude (2200 m). *Senecio tovari* is very well represented in our study area and our data clearly show that it should be considered a class characteristic species of *Echinopsio schoenii-Proustietea cuneifoliae*. According to our relevés, the single relevé presented by Galán de Mera et al. (2004) does not represent the real syntaxonomic status of *Senecio tovari*. *Stipa ichu* is not restricted to the community as described by Galán de Mera et al. (2004) but is a very common tussock grass ubiquitous in the Andes.
Luebert & Gajardo (2005) described the association *Chuquirago rotundifoliae-Polylepidetum rugulosae* for the northern Andean regions of Chile. In our survey we consider *Chuquiraga rotundifolia* to be characteristic of one association of our new class. The structure, floristic similarity and geographical distribution of the *Chuquirago rotundifoliae-Polylepidetum rugulosae* are very different. Our new class is typically a shrubland, not forest. No remnants of *Polylepis* forests are known from our region. In the south Andes of Peru *Chuquiraga rotundifolia* also grows outside *Polylepis* forests, in vegetation stands consisting exclusively of native and endemic species.
Diplostephio meyenii-Fabianion ramulosae described by Luebert & Gajardo (2005) is also geographically, ecologically and floristically completely different from our communities and has no characteristic species in common. Only three of our 71 species, all companion species. *Diplostephium meyenii* ocurs in the south of Peru (Brako & Zarucchi 1993), but has not been documented so far in Peruvian communities.
The association *Dunalio spinosae-Baccharidetum latifoliae* (Galán de Mera et al. 2003) is the typical vegetation of the dry puna occurring between Arequipa and Tacna in valleys close to farmland with a number of invasive species (e.g. *Baccharis latifolia,* absent in our study). Seibert (1993) considers this as a variable vegetation occurring close to terraces and towns, where the soil is usually much more fertile. In our study this community could not be distinguished because of differences in species composition, altitude, site characteristics, topography and bioclimatic conditions.
Polyachyro sphaerocephali-Puyetum densiflorae (Galán de Mera et al. 2009) is described for the slopes at 3750 m in El Colca valley, North of Arequipa and differs considerably from

our communities, sharing only a few companion species. *Puya densiflora* and *Polyachyrus sphaerocephalus* are absent from our study area.

The *Parastrephion lepidophyllae* Navarro 1993 has been described from slopes (3620–3710 m) in the southern part of the altiplano of Bolivia. The major difference in bioclimatic and geographical distribution is the absence of the diagnostic species in the vegetation of the Moquegua study area. The few shared species are mostly annual herbs and grasses (companions).

The community of *Tarasa urbaniana* and *Helogyne apaloidea* could not be related to one of the previously described higher syntaxa. Galán de Mera et al. (2004) mention the endemic shrub *Helogyne ferreyrae* (based on one relevé) conforming the subassociation *proustietosum berberidifoliae* (*Aristeguietio discoloris-Baccharidetum latifoliae*) in Lima (Central Peru). The community described for Moquegua does not fit this description as it misses most of the diagnostic species mentioned in that table and, in addition, differs strongly in geographical and altitudinal range as well as in floristic composition. Our community represents a vegetation type occurring in South Peru, whereas the subassociation described by Galán de Mera et al. (2004) is from central Peru.

The native tree species *Escallonia myrtilloides* has a very wide distribution and can be found along the humid tropical Andes from Costa Rica and Venezuela to the southwest of Bolivia and north of Chile. The community of *Escallonia myrtilloides* and *Polylepis quadrijuga* described from Colombia by Cleef (1981) and community of *Escallonia myrtilloides* and *Alnus acuminata* described from Costa Rica (Islebe et al. 1996) are both absent from Peru. Arroyo et al. (2010) defines that the lower limit of the alpine life zone in the South American Andes is hindered by the lack of a treeline over a considerable extension of the puna. According to our study, *Escallonia myrtilloides* communities can be found on the slopes >3600 m in the highlands of Moquegua. Puna dwarf forests of *Escallonia myrtilloides* are quite different from the paramo dwarf forests of *Escallonia myrtilloides* further north. It seems that *Escallonia myrtilloides* in our study area is at the southwestern limit of its distribution in Peru. Galán de Mera et al. (2002a) mention the occurrence of the species within the *Lantano-Chusquetea* class, which differs considerably in floristic composition, altitude and geographical zonation. Of the 42 species in our class consisting of very dense shrubland in disturbed areas, only two are shared.

Table 5. Synoptic table of the associations described and of communities from literature. It includes data from other studies of the vegetation in the Andean slopes of Peru. 1. Gutte (1986, Table 14, p. 361); 2. Galán de Mera & Vicente Orellana (1996, Table 1, p. 42); 3. Galán de Mera et al. (2002b, Table 4, p. 86); 4, 5, 6. Galán de Mera et al. (2003, Tables 2, 3, 13, p. 126–140); 7, 8, 9. Galán de Mera et al. (2004, Tables 8, 10, p. 104, 106); 10, 11. Galán de Mera et al. (2009, Tables 13, 14, p. 132–133); 12, 13. Luebert & Gajardo (2005, Tables 3, 7, p. 10, 19); 14. Navarro (1993, Table 7, p. 89): 15. Navarro & Maldonado (2002, p. 490). I. The species values correspond to the cluster centroid numerical calculations; II. The species underlined to the taxa restricted to this study. III. CS for the characteristic species of those predescribed classes. IV: Braun Blanquet Scale Method (+, r, 1, 2 & 3) applied for species presence in literature tables.

Country	**PERU**					**PERU**											**CHILE**		**BOLIVIA**	
Reference	Montesinos et al.					Gutte (1986)	Galán de Mera & Vicente Orellana (1996); Galán de Mera et al. (2002, 2003, 2004, 2009)										Luebert & Gajardo (1993)		Navarro (1993)	Navarro & Maldonado (2002)
Unit (references)						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Community (this study)	1	2	3	4	5															
Altitude (m)	3560–3700	3570–3700	3470–3650	3580–3610	3700	3600–3900	1000–3000	2500–2650	2980–4100	3450–4460	3010–3500	3450–3510	2200	3510	2700–2770	3744–3767	3100–3300	3500–3800	3500	-
Total area (m²)	395	441	377	120	225	-	-	550	100	100	700	200	100	100	700	47	964	150	500	100
Number relevés	16	13	12	4	1	34	9	7	-	-	10	4	1	1	7	5	7	4	17	-
No. of species	104	87	71	32	42	6	5	2	3	2	4	2	8	17	3	6	4	5	50	12
Shared species						1	-	8	-	3	-	-	2	7	8	2	1	1	15	4
Assoc. 1. Senecioni arnaldii-Exhalimolobetum weddellii																				
Puya ferruginea	2,5	0.2				1						3		1						
Senecio arnaldii	1,6																			
Gamochaeta humilis	0,6																			
Nama dichotoma	0,4																			
Exhalimolobos weddellii	0,5																			
Cryptantha peruviana	0,5																			
Tephrocactus verschaffeltii	0,3																			
Solanum excisirhombeum	0,2																			
Stenomesson sp. (#2107)	0,1																			
Gnaphalium lacteum	0,1																			
Assoc. 2. Mostacillastro gracile-Chuquigaretum rotundifoliae																				
Chuquiraga rotundifolia		2,2							+									r		
Mostacillastrum gracile		0,7	0.6																	
Caiophora cirsiifolia	0,1	1,2																		
Conyza sumatrensis var. *leiothe*	0,3	0,8																		
Subassoc. 2.1. phacelietosum pinnatifidae																				
Phacelia pinnatifida		0,4																	+	
Subassoc. 2.2. chuquiragetosum rotundifoliae = subass. typicum																				
Ipomoea minuta	0,1	0,3																+		
Plazia daphnoides	0,1	0,2																		
Subassoc. 2.3. chaptalietosum similis																				
Chaptalia similis		0,6		0,8	1,0															
Stipa obtusa		0,9	0,7																	
Sisyrinchium bracteosum		0,2																		
Aristeguieta ballii		0,2																		
Assoc. 3. Anredero diffusae-Diplostephietum meyenii																				
Subassoc. 3.1. diplostephietosum meyenii = subass. typicum																				
Anredera diffusa		0,5	1,6																	
Diplostephium meyenii			2,0														1			
Subassoc. 3.2. bomaretosum ovatae																				
Fuertesimalva echinata	0,2		1,1																	
Bomarea ovata			0,8																	
Dunalia spinosa			0,8								1									
Zephyranthes boliviana			0,3																	
Geranium core-core			0,2																	
Sedum reniforme			0,3									1			+	+				
Variant 3.2. *Calceolaria pisacomensis*																				
Sycios baderoa			0,5																	
Calceolaria pisacomensis			0,3																	
4. Community of *Cylindropuntia rosea* and *Helogyne apaloidea*																				
Helogyne apaloidea				2,5																
Tarasa urbaniana				1,8																
Nicotiana rustica				1,0																
5. Community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*																				
Escallonia myrtilloides					4,0			+												
Festuca dolichophylla					3,0															
Belloa longifolia					2,0															
Bomarea involucrosa					2,0															
Gomphrena meyeniana					2,0				+										+	
Ophryosporus heptantus					2,0				+											
Plantago tubulosa					2,0															
Tarasa tenuis					2,0															
Baccharis tricuneata					1,0															
Mancoa hispida					1,0														+	
Oenothera multicaulis					1,0															
Oenothera sp. (#2160a)					1,0															
Echinopsio schoenii-Proustietea cuneifoliae; Echinopsio schoenii-																				
Junellia arequipense	1,3	2,2	2,7						+						+					
Proustia cuneifolia	2,3	1,2	1,9	2,3			+												+	
Echinopsis schoenii	1,2	0,9	1,3																	
Sarcostemma solanoides	2,1	1,8	1,9	1,5											+					
Salvia oppositiflora	1,9	1,8	1,5	0,5		+														
Cumulopuntia unguispina	2,3	1,7	2,1	2,8	2,0				1											
Galinsoga mandonii	1,9	0,7	0,7	1,0	2,0															
Villanova oppositifolia	1,3	1,4	0,1	0,5																
Senecio tovari	0,9	1,4	2,5	2,0										2						
Bowlesia sodiroana	1,6		0,4																	
Oxalis megalorrhiza	1,5	2,0	1,7	2,0	1,0															
Viguiera lanceolata	2,0	1,8	0,5																	
Heliotropium microstachyum	0,6	0,5	0,8	1,5																
Lycianthes lycioides	0,6	1,2	1,5	0,8											+					

Unit (references)						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Community (this study)	1	2	3	4	5															
Lophopappus foliosus	0,9	2,4	0,8	1,0					+											
Gochnatia arequipensis		1,7	2,3												+					
Cheilanthes myriophylla	0,3	0,6	0,7																	
Peperomia scutaleifolia	0,9	0,8		0,3																
Cylindropuntia rosea	0,3	0,2	2,0	3,0	2,0															
Echeveria peruviana	0,4	0,3		1,5																
Aa mathewsii	0,2	0,2		0,5		+														
Paronychia setigera	0,7	0,9																		
Salpichroa tristis	0,2	1,0																		
Adesmia miraflorensis	0,3	1,0		2,8	2,0															
Neowerdermannia peruviana	0,3	0,6	0,5																	
Hypochaeris chillensis	0,4	0,3	0,5																	
Mirabilis expansa	0,6		1,0																	
Dalea cylindrica	0,6			2,3											1					
Ligaria cuneifolia	0,3	0,2	0,3		2,0															
Chenopodium incisum	0,3	0,5	0,3																	
Portulaca pilosa			1,2	1,0																
CS Opuntietea sphaericae																				
Ephedra americana	0,4	1,5	0,5			+	+												1	
Oreocereus leucotrichus			0,5															+		
CS Polypodio-Tillandsietea																				
Tillandsia capillaris	1,3	2,3	1,2	1,0	2,0															
Tillandsia usneoides		0,2	0,2									+			+					
CS Notholaenetea niveae																				
Notholaena nivea	1,1	1,8	1,3			2			+			1						+		
Cheilanthes pruinata	2,5	0,5	1,7		2,0				+						1	+	1			
Cheilanthes scariosa	0,1	0,5	0,2			+						+								
Woodsia monteviensis	0,1	0,4				+														
Cystopteris fragilis		0,2				+														
CS Lantano-Chusquetea																				
Mutisia acuminata var. *hirsuta*	0,6	0,4	0,9				+	+	+		1			2	+	+				
Austrocylindropuntia subulata			1,1						+		+			1	+	1				
CS Crassuletea connatae																				
Crassula connata	0,1																			1
CS Muhlenbergietea peruvianae																				
Chondrosum simplex	1,6	0,4	1,5	1,8	1,0										+				3	1
Muhlenbergia peruviana	1,0		0,6	2,3					+										1	1
Tarasa tarapacana	1,8	1,2	1,3	2,0	1,0														1	1
Tagetes multiflora	0,1								1										3	1
CS Baccharidetea latifoliae																				
Satureja boliviana	0,1	0,2																		
CS Calamagrostietea vicunarum																				
Tunilla soehrensii	0,4	0,7							1							+	+	+		
Lophopappus tarapacanus	1,4	1,2		1,0					1		+			1		1				
Quinchamalium procumbens	0,3	0,5	0,1	1,3	1,0	+			+											
Chersodoma jodopappa		0,4							1	+						+	+	+		
Luzula racemosa	0,4	0,2								+										
Basal community																				
Stipa ichu	2,1	3,3	2,1		3,0	+			1	1	+	+	1	1	+				2	
Nassella inconspicua	0,6	0,8	1,3	0,8															2	
Nassella asplundii	1,0								1	+									1	
Companions																				
Stevia macbridei	2,4	0,8	0,6		2,0															
Bidens andicola	1,4	1,4	0,7	0,8	2,0															
Eragrostis nigricans	1,9	0,5	0,7	1,8	2,0															
Cyperus seslerioides	0,8		1,0																+	
Calceolaria inamoena	1,0	1,1	0,3						+		+									
Erigeron pazensis	0,1	0,3																		
Lobivia pampana	0,4	0,9	0,7		1,0															
Pellaea ternifolia	0,3	0,4	0,6						+						+					
Valeriana radicata	0,3	0,4	0,6																	
Achyrocline ramosissima	0,8	0,4																		
Aristida adscencionis	0,2	0,5																		
Galium corymbosum	0,3	1,0	0,4		2,0	+														
Hieracium streptochaetum	0,4	0,2																		
Poa candamoana	0,5				2,0	1														
Nothoscordum fictile	0,8				2,0															
Spergularia fasiculata	0,8	0,6	0,6		1,0												r			
Facelis plumosa	0,7		0,5																	
Asplenium peruvianum	0,1	0,1																		
Chenopodium petiolare	0,1	0,2	0,4			+												+		
Lupinus paruroensis	0,4								+	+										
Cardionema ramosissimum	0,1	0,4															1	+	2	
Mutisia orbignyana		0,8			2,0				+											
Perezia pungens		1,3																		
Olsynium junceum		1,4				+														
Bromus catharticus		0,4																		
Oxalis moqueguensis	0,3	0,2	0,1																	
Bartsia peruviana		0,2																		
Belloa piptolepis		0,2								+										
Native weeds, invasive																				
Nothoscordum andicola	0,8		0,2																	
Ullucus tuberosus subsp. *abori*	0,3																			
Chamaecyse serpens	0,9		1,3	1,3																
Tagetes filifolia	0,1																			
Trifolium amabile	0,8																		1	
Cyclospermum leptophyllum	0,4																			
Daucus montanus	0,3	0,2	0,5																	
Tagetes minuta			0,1																	
Chenopodium ambrosioides			0,3																	
Solanum tuberosum	0,1				1,0															
Equisetum bogotense					2,0															
Juncus ebracteatus					2,0															
Exotic species																				
Galium aparine	0,3					+														
Medicago lupulina	0,3				2,0															
Erodium cicutarium	0,4		0,6	1,8	2,0						+									
Kikuyuochloa clandestina	0,1				2,0															
Taraxacum officinale	0,1																			
Rumex crispus	0,3																			
Sonchus oleraceus	0,1				1,0															
Solanum nigrum		0,2																		
Capsella bursa-pastoris			0,2					+												

Vegetation series

From the available climatic information (Fig. 2), it is not possible to definitively delimit the bioclimatic series in the study area, but based on the distribution of the phytosociological units we will present a new proposal.

Unfortunately, the only climate data available for the associations belonging to *Salvion oppositiflorae* was from the Ubinas meteorological station (3200 m) and Ichuña (3800 m). From our results and by comparison with Rivas-Martínez & Tovar (1982), Rivas-Martínez et al. (1999), Luebert & Gajardo (2005) and Kuentz et al. (2007) we conclude that our study sites lie between the boundaries of the higher levels of the Supratropical semiarid and the Orotropical subhumid bioclimatic belts. Climatic data available indicate that at Ubinas station the total rainfall accumulation is 243 mm/year and at Ichuña station, 460 mm/y for the period 2008–2009. It is not possible to use these data for an accurate description of the bioclimate in our study region. In relation to exposition and topography, the boundaries will differ in altitude.

In this paper we have introduced the Prepuna which is characterised by shrubby vegetation in a zone below 3800 m, a synonym, the subpuna, is used by Kuentz et al. (2007). Galán de Mera et al. (2003) assign our study region to the semiarid acidophilous series of the *Corryocactus brevistylus-Weberbauerocereo weberbaueri*. After thoroughly analysing the vegetation composition, biogeography, climate and topography of these regions, we conclude that the confluence of the Tambo and Ichuña rivers belongs to a completely distinct class. Between 3400 (<3300) and 3700 m, *Echinopsio schoenii-Proustietea cuneifoliae* (here described) and *Calamagrostietea vicunarum* above 3800 m. We base this contention on the absence of the diagnostic species for *Corryocactus brevistylus* and *Weberbauerocereus weberbaueri*. We assume that the boundary between the *Opuntietea sphaericae* and the *Echinopsio schoenii-Proustietea cuneifoliae* lies in the canyon between Yalagua (16°16'S and 70°45'W, 3300 m) and Matalaque (16°24'S and 70°45'W, 2800 m).

We propose the following climatic thermotypes and zonation in the Tambo river upper slopes of Moquegua:

Land use and conservation

In our study area free-ranging livestock influence the vegetation: sheep and cows influence the Prepuna shrublands and at higher altitude sheep and alpacas influence the puna. Disturbance by fire is limited to the shrublands and grasslands. There is little detailed information about the extent and intensity of overgrazing and degradation in the Peruvian Andes (Lozada 1991). In recent decades, some agriculture has been intensified and soil degradation has increased due to the extensive use of pesticides and chemical fertilisers, and overgrazing. The absence of soil conservation practices, together with overgrazing of the fragile Andean ecosystems, has led to severe rangeland degradation in the Andes (Lozada 1991). More recently Paduano et al. (2010) indicate that Lake

Titicaca lies close to the lower limit of puna vegetation which has been substantially modified by human activity.

In the near future, exploitation of natural resources will increase and may negatively affect the natural biodiversity. The conservation of the Moqueguan mountain environments should be prioritised for the preservation of these fragile and diversed ecosystems (Montesinos-Tubée 2011a). Fires may occur elsewhere in the studied region, especially during the driest days of the year of high radiation, we recommend to reduce the practice of burning the hills to enhance the biodiversity equilibrium and evade the loss of floral and faunal species. We recommend curtailing the introduction of exotic tree species for forests in the region and instead the use of native species such as *Escallonia myrtilloides, Buddleja coriacea, Polylepis besserii* and *Kageneckia lanceolata*.

Table 6. Climatic thermotypes and zonation in the Tambo river upper slopes of Moquegua[17].

In table 6 and figure 5 the climatic thermophytes and zonation is presented for the mountain regions of North Moquegua.

Altitudinal range	**Bioclimate**	**Puna**	**Units**
(Rivas-Martínez & Tovar 1983; Huber & Riina 1997; Kuentz et al. 2007.			
<2800–3000 m	Supratropical	Prepuna, dry shrublands	*Opuntietea sphaericae* (*Corryocactus*)
*			
3000(3500)–3800 m	Orotropical	Prepuna, Subpuna, shrublands	*Echinopsio schoenii-Proustietea cuneifoliae*
3800–4300 m	Orotropical	Puna	*Calamagrostietea vicunarum* (*Puya raimondii, Parastrephia*)
4300–4800 m	Cryorotropical	Superpuna	*Calamagrostietea vicunarum* (*Azorella, Nototriche*)
4800–5000> m	Nival	Puna subnival	*Mniodes, Xenophyllum*

17 Data from this table was modified and a new scope is presented in the synthesis (Chapter 8).

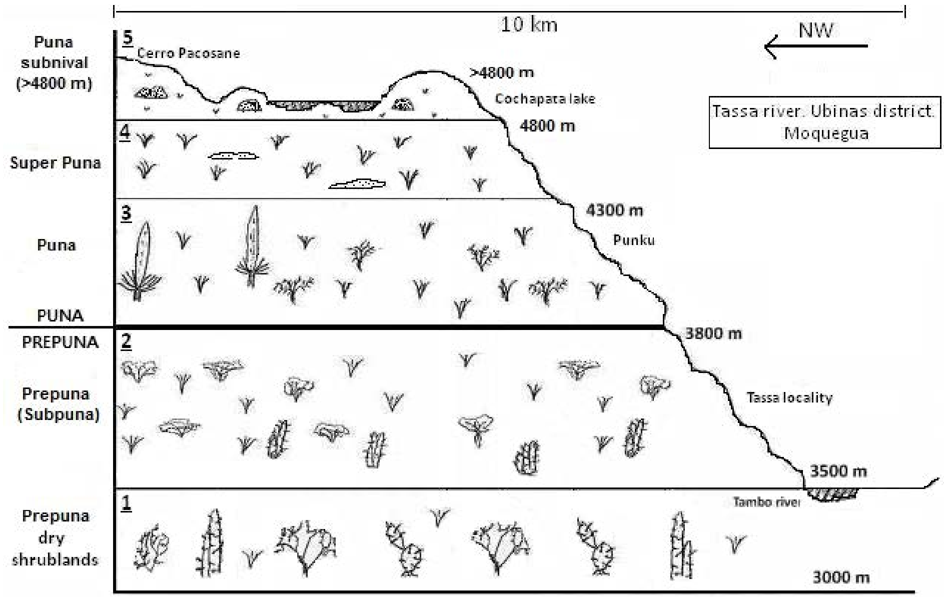

Figure 5. Schematic representation of the vegetation zonation from the upper Tambo river valley near Tassa town in the Moquegua Andes.

CHAPTER 4

The Puna vegetation of Moquegua, South Peru: Chasmophytes, grasslands and Puya raimondii stands

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Phytocoenologia 45(4): 365–397, 2015

Abstract

The phytosociology and ecology of puna vegetation in twelve localities at an altitude of 3750–4500 m in northern Moquegua (South Peru) have been studied. The study area has a pluviseasonal climate with summer rainfall. Using TWINSPAN, CANOCO 4.5 and PC-ORD, 157 phytosociological relevés were analyzed. For each community, the syntaxonomy, floristic diversity and relation with environmental variables are discussed. 210 vascular plant species belonging to 131 genera and 52 families were recorded. Three main vegetation types were distinguished: 1. chasmophyte vegetation composed of a great diversity of shrubs, dwarf shrubs, ferns and annuals, 2. *Puya raimondii* stands characterized by considerable species richness in shrubs, grasses and herbs, and 3. extensive puna grasslands influenced by grazing. The zonal vegetation of the supratropical and orotropical bioclimatic belts was represented by two phytosociological classes: *Argyrochosmetea niveae* (chasmophytes) and *Calamagrostietea vicunarum* (*Puya raimondii* and puna grasslands). Within the *Argyrochosmetea niveae* and *Salpichroetalia glandulosae*, the new alliances *Argyrochosmo niveae-Neowerdermannion peruvianae* and *Hypochaerido mucidae-Loricarion graveolentis* were distinguished, including six associations consisting of steep rock and crevice shrublands on lithosols. Within the *Azorello compactae-Festucion orthophyllae* (*Calamagrostietea vicunarum*) two associations with four subassociations and two communities were distinguished comprising grasslands and *Puya raimondii* stands. One association was described in the *Calamagrostion minimae*. The puna vegetation of Moquegua hosts rare, endangered and/or protected plant species in Peru. The vulnerability of the flora and vegetation in the mountains of Moquegua is briefly discussed.

Keywords: Andes, *Argyrochosmetea niveae, Calamagrostietea vicunarum*, Peru, phytosociology, syntaxonomy.

Introduction

Puna is the name given to extensive highlands in the central and southern Andes of South America and particularly to their distinctive alpine grassland vegetation (Cabrera 1968; Navarro 1993; Galán de Mera et al. 2003, 2009, 2011b, 2014; García & Beck 2006; Montesinos et al. 2012). Weberbauer (1912, 1945) distinguished the puna from the vegetation of the Altiplano plateaus, which is dominated by dwarf grasses, rosettes and cushion plants, although these occur also in the puna albeit with lower frequency. For the evergreen shrub formations occurring above 4200 m, Weberbauer (1945) used the term *tolares.* In the traditional vegetation classification for Bolivia, the term 'puna' has been used for the vegetation of the high plateaus of the Central Andes (Beck & García 1991; García & Beck 2006). Kuentz et al. (2007) characterized the southern Andes of Peru as 'mountainous steppe and puna', and considered the puna to be dry vegetation located on the Altiplano and on the mountain slopes, above 3000 m.
The tropical Andes belong to the world's biodiversity hotspots (Myers et al. 2000). The dry puna is one of its largest pastoral ecosystems, with a unique assemblage of shrubs, tussock grasses, cushion and matforming species (Smith 1994). The floristic composition of the dry puna of South Peru is affected by grazing (Catorci et al. 2014). In the north of Moquegua (in South Peru) the puna vegetation is influenced by the rainy season (December to April) and is characterized by shrubs, dwarf shrubs, tussock grasses, annual herbs and ferns. Most of the Peruvian puna grasslands are grazed by livestock (predominantly llamas and alpacas) (Wilcox et al. 1986). The continuous fumarolic activity of the Ubinas volcano (Rivera et al. 2014) could have strong negative effects on the plant communities in north Moquegua.
The term chasmophyte (Antonsson 2012) refers to plant species that grow in crevices on steep rocky slopes with lithosols. Although relatively species-poor, the vegetation of alpine rock communities is of great interest as it is adapted to harsh and extreme environments (Nowak et al. 2014a, 2014b) in which many endemics can be found. With seepage or run-off water, rocks can offer wet microhabitats even in dry areas (Deil 2014) and as such usually host species, including several endemics, which do not occur in adjacent ecosystems. Other authors (Mucina et al. 1990; Escudero 1996; Caiafa & Da Silva 2007) present important studies of chasmophytic vegetation and the significance of their functional role. In Peru, Gutte (1986) and Galán de Mera et al. (2003, 2014) identified different plant communities of chasmophytic vegetation in the Arequipa and Tacna provinces representing the class *Argyrochosmetea niveae*. The vegetation of this class develops on basalt crags and includes two orders with an extensive Andean distribution (Seibert & Menhofer 1992).
Montesinos et al. (2012) presented an overview of the climatic thermotype zonation of the upper Tambo River in the Moquegua region. Gutte (1986) and Galán de Mera et al. (2003, 2009) described the chasmophyte vegetation of the central and south Andes of Peru. Gutte (1985) and Galán de Mera et al. (2009) also described the phytosociology

of the giant bromeliad *Puya raimondii*. Other authors (Weberbauer 1945; Pedrotti & Venanzoni 1986; Venero 2001; Sgorbati et al. 2004; Vadillo et al. 2007; Lambe 2009; Hornung-Leoni et al. 2013; Vargas Sierra 2013; Montesinos-Tubée 2014a) also refer to the presence of this vegetation and the genetic variation of *P. raimondii* in Peru and Bolivia. The stands of *P. raimondii* commonly known in Spanish as 'rodales', were recently inventoried in the Moquegua region by Montesinos-Tubée (2011a, 2014a). In addition, several authors have studied the vegetation of the puna in the Central Andes: Galán de Mera et al. (2002a, 2003, 2004, 2009, 2011, 2012, 2014), Gutte (1980, 1985, 1986, 1987, 1988, 1995), Lambrinos et al. (2006), Luebert & Gajardo (2000, 2005), Montesinos et al. (2012), Montesinos-Tubée et al. (2015a), Navarro (1993), Navarro & Maldonado (2002), Rivas-Martínez & Tovar (1982), Ruthsatz (1977), Seibert & Menhofer (1991, 1992, 1993). However, prior to the present research, the ecology and vegetation structure of the high Andes of north Moquegua had not been studied (Montesinos et al. 2012).

Thus, the aim of this article was to: (a) perform a syntaxonomic characterization of puna vegetation in South Peru, based on full and synoptic tables, (b) determine the distribution of chasmophytic and grassland vegetation in Moquegua (South Peru), (c) find an explanation for their rare and local occurrence as well as floristic diversity, and (d) evaluate the importance of Puna rocky slopes, cliffs and grasslands as habitats for specific vegetation types, and for some endemic plant species in Moquegua (South Peru). We hypothesize that environmental factors such as altitude, slope aspect and angle, cover of rocks and stones, and soil properties as well as the disturbance caused by grazing and fire are important environmental factors affecting the diversity and species composition of the puna vegetation. The relations between plant communities and these factors are described.

The present contribution is an extension of the study by Montesinos et al. (2012) that described the prepuna vegetation found at an altitude between 3470 and 3700 m in the Moquegua department. The study here extends the previous observations and represents an altitudinal range of 3750–4500 m.

Study area

The research was conducted in an area of approximately 550 km² in the districts of Ichuña, Ubinas and Yunga, in the General Sánchez Cerro province in the north of the department of Moquegua, South Peru, located between 70°44'33", 26'59" W and 16° 06'37", 16'30" S (Fig. 1, Table 1). Average annual precipitation at the Ichuña meteorological station (at 3790 m) is 460 mm with over 80% of the annual rainfall between December and April. The mean minimum temperature is 3.7 °C and the mean maximum is 19.4 °C (Servicio Nacional de Meteorología e Hidrología del Perú 2013). Precipitation is markedly seasonal. Soil moisture ranges from 0 in the dry season to below 10% in the rainy season (Montenegro et al. 2010).

The study area is located in the high altitude sectors of the northwest Andes between 3750 and 4500 m. The bedrock is volcanic and sedimentary with intercalations of conglomerates and sand; ravines and crevices have infill of sandy silt and calcareous sediment (EIAS-PEC 2009).

The fieldwork area comprises the grasslands and rocky slopes of the two mountain chains of volcanic origin that form the watersheds of the upper Tambo, Sefincane, Paltuture and Ichuña rivers and their tributaries.

Methods

Phytosociology, classification and data collection

The sample plots were preferentially selected adopting homogeneity criteria as defined by the Zurich-Montpellier method (Braun-Blanquet 1979) and stratified by rocky cliffs, scrubland, grassland with tussocks, and *Puya raimondii* vegetation. Fieldwork was conducted during March and April in four years: 2009, 2011–2013. A total of 166 relevés was made in 12 sites. The area covered by a relevé was 25 m² or 36 m² for grasslands and

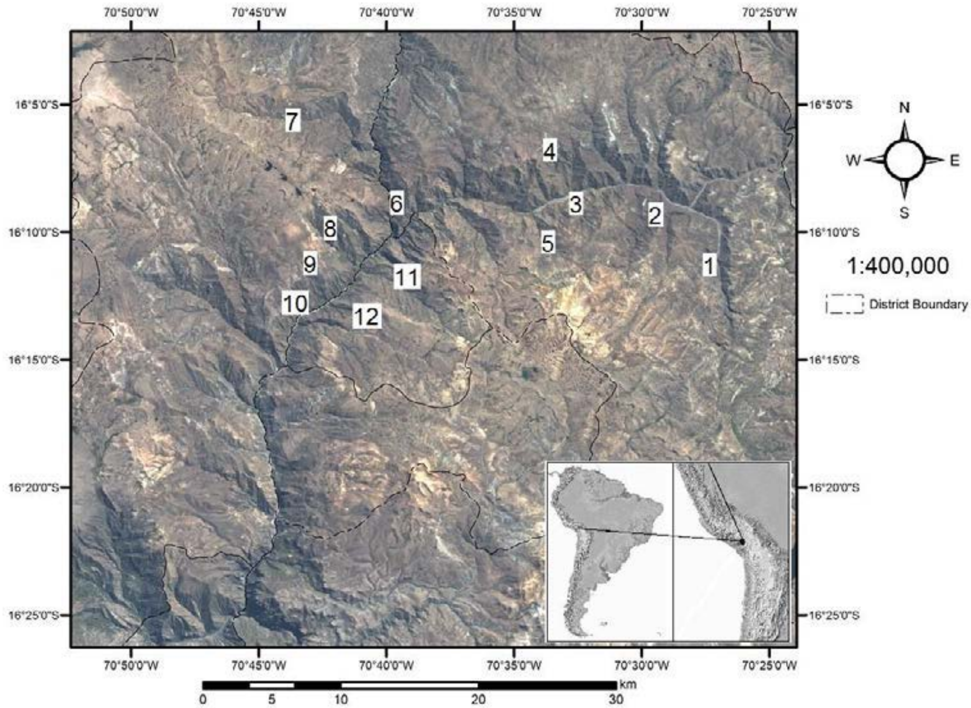

Figure 1. Location of the upper reaches of the Tambo and Ichuña rivers in the Andes of Moquegua, Peru. The black broken lines indicate the district boundaries. The numbers show the locations of the studied sites as listed in Table 1. Image source: Landsat 7 Enhanced Thematic. Mapper (ETM+) Acquisition date = 10 May, 2001. Glovis Visualization Portal (http://www.glovis.usgs.gov), a part of the Earth Resources and Science Center (EROS) of the USGS.

Table 1. Overview of parameters for each research site (1–12) in the puna of the Andes of Moquegua, Peru. #rels. = number of relevés at the site in question, year = year(s) in which fieldwork was done, Elevation = altitudinal range where the relevés were set out, Slope = slope angle.

	Locality	District	# rel.	Year	Lat S	Lon W	Elevation (m)	Slope (°)	Aspect	Environment
1	Tolapampa	Ichuña	4	2012	16°09'	70°27'	4000–4250	30–90	E-S	grassland, chasmophyte
2	Italpallune	Ichuña	10	2009	16°09'	70°29'	3900–4050	30–45	N-NNE	grassland
3	Rocky slopes near Ichuña	Ichuña	9	2009	16°08'	70°32'	3800–4050	30–80	S-SW, N	grassland, *Puya raimondii*
4	Yanapuquio - Condorwasi (Yanahuara locality)	Ichuña	12	2012	16°06'	70°33'	4250–4500	40–60	SE	grassland, chasmophyte
5	Santa Cruz de Oyo Oyo	Ichuña	9	2009	16°10'	70°34'	4050–4250	40–50	N-NW	*Puya raimondii*
6	Sefincane	Ichuña	6	2013	16°09'	70°39'	3950–4000	60–80	S-W	chasmophyte
7	Coalaque	Ubinas	9	2009	16°05'	70°44'	4300–4500	15–30	NE	grassland
8	Pirhuani, Rancho, Punku (Tassa locality)	Ubinas	30	2009–2013	16°10'	70°42'	3900–4470	30–50	N-NE, SW-SE	grassland, *Puya raimondii*
9	Patune	Ubinas	16	2011–2	16°11'	70°43'	4050–4200	10–80	S, W	grassland, chasmophyte
10	Qellepunku	Ubinas	6	2013	16°12'	70°42'	3750–3850	50–60	SW	chasmophyte
11	Kasullama - Sura	Yunga	38	2009–2013	16°11'	70°39'	3900–4500	5–100	N, S, W	chasmophyte, *Puya raimondii*
12	Pampilla	Yunga	8	2013	16°13'	70°41'	4100–4250	5–35	N, W	grassland, chasmophyte

Puya raimondii stands and 1m², 4m², or 25 m² for chasmophyte communities (plot size depended on accessibility of sites and homogeneity of the vegetation, as well as on the presence of shrubs such as *Plazia daphnoides*). For each relevé, the presence of species was noted and their percentage cover was estimated (Mueller-Dombois & Ellenberg 1974; Knapp 1984). For computer calculations the percentage values were transformed into a nine-point ordinal cover/abundance scale (Westhoff & Van der Maarel 1973): 1% = 1; 2% = 2; 3% = 3; 4–7% = 4; 8–20% = 5; 21–37 = 6; 38–68% = 7; 69–88% = 8 and 89–100% = 9. In chasmophytic and grassland units we noted the cover by vascular plants only. The presence of bryophytes and lichens was noted, but the species were not identified. The character and differential species in the description of the communities are mentioned in order of their diagnostic value.

Newly described syntaxa were named and formed according to the rules of the International Code of Phytosociological Nomenclature (Weber et al. 2000) and defined after consulting Galán de Mera (2005). The relevés were classified by means of TWINSPAN (Hill 1979) and 15 groups were selected from the divisions; syntaxonomic vegetation tables were constructed and a Farthest Neighbor Clustering performed (PC-ORD, Sørensen, Bray-Curtis Distance Measure) (McCune & Mefford 1999) to show the hierarchical similarity structure of the syntaxa and to compare related communities from literature (Peru: Rivas-Martínez & Tovar 1982; Gutte 1985, 1986; Galán de Mera et al. 2003, 2004, 2009, 2011b, 2012a, 2014; Montesinos et al. 2012; Bolivia: Seibert & Menhofer 1991, 1992; Navarro 1993, Navarro & Maldonado 2002; Chile: Luebert & Gajardo 2000, 2005). For calculations in the dendrogram analysis, presence class values I-V (1–5) were used, both in our communities and in those from referenced sources. In total, 77 communities were included in the analysis. All species were used, except casual ruderals and introduced species.

Detrended Correspondence Analysis (DCA; CANOCO 4.5, Ter Braak & Šmilauer, 2002) was used to study the relation between species composition and environmental variables. Based on the data of our plant communities (1–15, Appendix A1), all 210 vascular plant species were included in the analysis. In the synoptic table (Appendix A1) species constancies are given in percentage values. Full tables are presented in appendices (Appendix 3, 4 and 5). We ensured that no sample plots traversed ravines, clefts or streams. In chasmophytic environments, sample plots were selected on bare rock that included soil pockets and crevices but had no contact with grassland vegetation. For each relevé we collected data on altitude (meters above sea level = m a.s.l.), slope inclination (degrees) and slope aspect (compass), cover of rocks and stones (percent). Within each relevé, five subsamples were taken from the upper 10 cm of the soil and combined into one bulked sample for pH analysis in the laboratory (only for the relevés done in 2009). The presence of manure was determined by the amount of dung found in each relevé and classed as 0: absence; I: 1–30%; II: 31–70%; III: >71% (dung cover). Grazing intensity was determined by the percentage of tussock grasses showing signs of grazing at the moment of field analysis, and was later transformed into I-III values.

The Farthest Neighbor Clustering was done on the basis of the communities 1–31 and 275 species (Appendix A1) which included species and community types found by Navarro (1993), Luebert & Gajardo (2005) and Galán de Mera et al. (2003, 2009, 2011b). The first cluster analysis revealed an outgroup (45 communities by Gutte 1985, 1986; Seibert & Menhofer 1991, 1992; Luebert & Gajardo 2000, 2005; Galán de Mera et al. 2003, 2004, 2009, 2012a, 2014; Navarro & Maldonado 2002, and Montesinos et al. 2012) which was removed prior to the second run.

The environmental variables rocks, stones, slope degree and the vegetation cover were presented as box-and-whisker charts and a distribution chart for altitude.

Floristics

The plant species were identified directly in the field; unidentified species were collected and later deposited in various herbaria (USM, HUSA, MOL, CPUN, HUPCH, CUZ, HSP, MO, L; for codes see Index Herbariorum, http://ciweb.nybg.org/science2/IndexHerbariorum.asp). Information on the taxonomy and species distribution were obtained from the literature (Arakaki & Cano 2003; Brako & Zarucchi 1993; Franco et al. 2004; Galán de Mera et al. 2003, 2009, 2012a; Linares Perea 2005; Schwarzer et al. 2010; Talavera 2010; Ostolaza 2011; Montesinos-Tubée 2011a, 2012b, 2013a,b; Montesinos et al. 2012; Britto & Arana 2014; Freire et al. 2014).

Hypochaeris mucida occurs in our study area as its variety *integrifolia*. This taxon occurs in the Peruvian departments of Puno (southern part) and Moquegua (northern part); see also Brako & Zarucchi (1993), Beltrán et al. (2007), Tropicos (2014). *Plantago sericea* occurs as its subspecies *sericea* which is distributed in the central and south Andean mountains of Peru (Rahn 1981, Brako & Zarucchi 1993, Tropicos 2014)

Results and Discussion

Syntaxonomic overview

Class: *Argyrochosmetea niveae* Gutte 1986
Order: *Salpichroetalia glandulosae* Galán de Mera, Cáceres & González 2003
Alliance: *Argyrochosmo niveae-Neowerdermannion peruvianae* Montesinos-Tubée, Cleef & Sýkora 2015
Typus: *Neowerdermannio peruvianae-Festucetum weberbaueri* Montesinos-Tubée, Cleef & Sýkora hoc loco (Appendix 3)

1. *Plantagini sericeae-Plazietum daphnoidis* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 5, Appendix 3)
2. *Phacelio secundae-Ribesetum brachybothryos* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 9, Appendix 3)
3. *Neowerdermannio peruvianae-Festucetum weberbaueri* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 19, Appendix 3)

Alliance: *Hypochaerido mucidae-Loricarion graveolentis* all. nov.
Typus: *Hypochaerido mucidae-Paronychietum muschleri* Montesinos-Tubée, Cleef & Sýkora hoc loco (Appendix 3)

4. *Hypochaerido mucidae-Valerianetum nivalis* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 24, Appendix 3)
5. *Paronychio ubinensis-Hypochaeridetum mucidae* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 34, Appendix 3)
6. *Hypochaerido mucidae-Paronychietum muschleri* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 49, Appendix 3)
7. Community of *Asplenium triphyllum* and *Polystichum orbiculatum* (Representative relevés: 55–58, Appendix 3)

Class: *Calamagrostietea vicunarum* Rivas-Martínez & Tovar 1982
Order: *Parastrephietalia lepidophyllae* Navarro 1993
Alliance: *Azorello compactae-Festucion orthophyllae* Galán de Mera, Cáceres & Gonzáles 2003 (Supplements S2, S3)
Parastrephio quadrangularis-Festucetum dolichophyllae Galán de Mera, 2011 (surveyed in Appendix A1).
Parastrephio lucidae-Festucetum orthophyllae Galán de Mera, Cáceres & Gonzáles 2003 (surveyed in Appendix A1).

8. *Baccharido tricuneatae-Puyetum raimondii* Galán de Mera, Linares Perea, Campos de la Cruz & Vicente Orellana 2009 (Appendix 4)

8.1 *senecionetosum ferreyrae* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 10, Appendix 4)

8.2 *ageratinetosum sternbergianae* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 28, Appendix 4)
8.3 *lupinetosum cuzcensis* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 35, Appendix 4)
8.4 *calamagrostietosum heterophyllae* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 49, Appendix 4)

9. *Sisyrinchio rigidifolii-Parastrephietum quadrangularis* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 3, Appendix 5)
10. Community of *Misbrookea strigosissima* and *Stipa ichu* (Representative relevés: 21–29, Appendix 5)
11. Community of *Plagiobothrys humilis* and *Stipa ichu* (Representative relevés: 30–38, Appendix 5)

Alliance: *Calamagrostion minimae* Rivas-Martínez & Tovar 1982 (Appendix 5)

12. *Baccharido caespitosae-Azorelletum diapensioidis* Montesinos-Tubée, Cleef & Sýkora 2015 (Typus: Rel. 42, Appendix 5)

Chasmophytic vegetation (*Argyrochosmetea niveae*)

The class ***Argyrochosmetea niveae*** comprises the vegetation growing in rock crevices and on cliffs in the central Andean mountains. Gutte (1986) described the class *Argyrochosmetea niveae* as occurring at an altitude of 2500–3500 m in Junín (Central Peru), with *Argyrochosma nivea,* a species characteristic of rock crevices. Galán de Mera et al. (2003) confirmed the presence of this species in the south of Peru, and we refer to the *Argyrochosmetea niveae* based on the occurrence of certain common chasmophytes such as *Argyrochosma nivea, Cheilanthes pilosa, Cystopteris fragilis* and *Woodsia montevidensis*. Galán de Mera et al. (2012b) refers to the alliance *Cheilanthion pruinatae* as commonly occurring on constructed rock walls near Andean roads and on the edges of agricultural terraces. However, we consider *Cheilanthes pruinata* to be only a companion species, because of its occurrence outside chasmophytic habitats and its common presence in grasslands and scrublands. The character species of the *Argyrochosmetea niveae* (*Woodsia montevidensis*, *Cheilanthes pruinata, Cystopteris fragilis* and *Bromus catharticus*) are considered to be widely distributed in both temperate and non-temperate regions (Tryon & Stolze 1989, 1991; Tropicos 2014). We identified these species in different ecosystems ranging from arid ecosystems to the superpuna. In this paper we classify them as companions which are not particularly characteristic of the chasmophytic class *Argyrochosmetea niveae* as they also occur in other classes. The communities we describe in the present paper under *Argyrochosmetea niveae* have some character species in common with the *Senecioni culcitioidis-Valerianetum nivalis* (Galán de Mera et al. (2003), *Woodsio montevidensis-Cheilanthion pruinatae* (Galán de Mera et al. 2012b) and *Asplenio triphylli-Melpomenetum moniliformis* (Galán de Mera et al.

2014) from the *Belloo schultzii-Salpichroion glandulosae* as described by Galán de Mera et al. (2003, 2012b), such as *Asplenium peruvianum, Asplenium triphyllum, Belloa schultzii, Cheilanthes pruinata, Galium corymbosum, Salpichroa glandulosa, Valeriana nivalis, Woodsia montevidensis,* and the companion *Ribes brachybothrys,* but were described from undisturbed rocky slopes, have a very different species composition and greater species richness.

The order ***Salpichroetalia glandulosae*** includes the chasmophyte vegetation of steep basalt cliffs from South Peru. In Moquegua it is represented at altitudes ranging from 3750 to 4500 m.
Character species: *Belloa schultzii, Bomarea dulcis, Cheilanthes pilosa, Luzula racemosa, Pellaea ternifolia, Peperomia scutellaefolia, Ribes brachybothrys, Salpichroa glandulosa, Saxifraga magellanica* and *Senecio sublutescens*.
A number of chasmophytic associations and communities (3–7, Appendix A1) gradually appear and may co-occur up to 4500 m. The *Phacelio secundae-Ribestum brachybothrys* occurs throughout the zone of the puna grasslands.

Alliance: ***Argyrochosmo niveae-Neowerdermannion peruvianae*** (Appendix A1, col. 1–3; A2, col. 1–3; Fig. 2, 3)
Physiognomy, composition and distribution: The alliance is represented by *Argyrochosma nivea* distributed in rock crevices in the highlands of Peru, Bolivia and NW Argentina (Brako & Zarucchi 1993; Tropicos 2014). *Neowerdermannia peruviana* is locally distributed in the highlands of the departments of Moquegua and Tacna (Brako & Zarucchi 1993; Montesinos-Tubée 2011b) inhabiting rock crevices. It borders on the *Echinopsio-Proustietea* from the prepuna communities (Montesinos et al. 2012) in the Ubinas and Yunga districts except in the Ichuña district, where its boundaries are with the puna communities of Calamagrostietea vicunarum (Rivas-Martínez & Tovar 1982). The alliance is distributed between 3750 and 4500 m. Based on 22 relevés we distinguished three new associations that grow on steep rocky slopes where basalt cracks that contain subhumid soils.
Character and differential species: The alliance is characterized by *Argyrochosma nivea, Neowerdermannia peruviana* and *Phacelia pinnatifida*. Differential species against the other chasmophytic alliance are *Coreopsis fasciculata, Oxalis megalorrhiza, Spergularia fasciculata, Stipa ichu* and *Tillandsia capillaris.*
The new alliance of *Argyrochosmo niveae-Neowerdermannion peruvianae* is based on the characteristic co-occurrence of the fern *Argyrochosma nivea* and *Neowerdermannia peruviana,* the latter being an endemic species of cactus in the Moquegua and Tacna regions (Brako & Zarucchi 1993; Arakaki et al. 2006; Montesinos-Tubée 2011b). This alliance comprises three new associations with a species combination never previously reported in phytosociological studies.

1. *Plantagini sericeae-Plazietum daphnoidi*s (Appendix A1, col. 1; A2, col. 1; Fig. 2)
Physiognomy and composition: Chasmophytes growing (sometimes abundantly) in rock crevices with fissures in steep basalt cliffs and composed of shrubs (0.4–1.5 m), annual herbs, ferns and grasses. The vegetation cover is 15–20%. The shrub layer is composed of *Plazia daphnoides* and, with less cover, also of *Lophopappus tarapacanus* and *Salpichroa glandulosa.* In the herb layer, annuals less than 15 cm tall, such as *Cardionema ramosissimum, Galium corymbosum, Hieracium streptochaetum, Oxalis megalorrhiza* and *Peperomia scutellaefolia* are common. The dwarf shrub *Plantago sericea* and the tussock grass *Stipa ichu* (1 m tall) are constant. The dwarf cactus *Neowerdermannia peruviana* has low cover. Several fern species can be found on these rocky slopes, together with a varied cover of bryophytes.
Character and differential species: Character species are *Plantago sericea, Plazia daphnoides and Polypodium pycnocarpum. Cheilanthes scariosa, Cheilanthes myriophylla, Aa matthewsii* and *Pellaea ternifolia. Crassula connata, Hieracium streptochaetum, Muhlenbergia peruviana* and *Tagetes multiflora* are differential species against the other communities of the *Argyrochosmo-Neowerdermannion*. Other differential species with low cover include: *Lophopappus tarapacanus, Oreocereus hendriksenianus, Puya ferruginea, Triniochloa stipoides.*
Ecology and distribution: The *Plantagini sericeae-Plazietum daphnoidis* grows at 3750–3850 m on 50–60° SW-facing outcrops. It occurs between the *Echinopsio schoenii-Proustietea cuneifoliae* at lower altitudes and the *Calamagrostietea vicunarum* at higher altitudes. The metamorphic rock outcrops are widespread on the upper Tambo River valley slopes between 3750 and 4000 m.

2. *Phacelio secundae-Ribesetum brachybothryos* (Appendix A1, col. 2; A2, col. 2; Fig. 3)
Physiognomy and composition: Vegetation cover can reach up to 40%, with high frequency of shrubs and annuals. The shrub layer (0.8–1.5 m) is composed of *Bomarea dulcis, Ribes brachybothrys* and *Salpichroa glandulosa.* In general, the herb layer is no taller than 10 cm, only *Valeriana interrupta* can reach 30 cm. Dwarf shrubs with a height of 1–10 cm consist of *Belloa piptolepis, Paronychia weberbaueri* and *Senecio klattii.* Ferns and bryophytes are less abundant and less frequent. The cushion-forming *Azorella compacta* develops within rock crevices, sometimes on near-vertical surfaces. This association is classified on the basis of ten relevés with a total of 27 vascular plant species.
Character and differential species: Character species are *Phacelia secunda* and with a very low frequence also *Paronychia weberbaueri* and *Senecio klattii.* The latter two species despite having a low frequency are only known to occur in this community. *Bomarea dulcis* and *Ribes brachybothrys* are differential within the *Argyrochosmo niveae-Neowerdermannion peruvianae*.

Ecology and distribution: The vegetation grows at 4100–4500 m, on E, S and SE-facing slopes with an inclination of 30–90°. The clayey soils on the rocky slopes are characterized by high concentrations of iron oxides and are also known as Ultisols (USDA classification). They can be found in the Ichuña River valley at the boundary with grassland vegetation above 4000 m.

3. *Neowerdermannio peruvianae-Festucetum weberbaueri* (Appendix A1; A2, col. 3; col. 3)

Physiognomy and composition: High diversity of shrubs, annual herbs and tussock grasses. The abundance of the dwarf cactus *Neowerdermannia peruviana* (1–4 cm, 8–12%) and the tussock grass *Festuca weberbaueri* are characteristic of this community. The shrub layer is composed of *Aristeguietia ballii, Clinopodium bolivianum*[18]*, Coreopsis fasciculata, Salpichroa glandulosa, Senecio sublutescens* and *Viguiera procumbens,* reaching up to 1.6 m in height. Several annuals, the most frequent of which are *Peperomia scutellaefolia* and *Vasquezia oppositifolia*, compose the herb layer. The ferns *Asplenium peruvianum, Cheilanthes pruinata, Elaphoglossum minutum, Argyrochosma nivea* and *Woodsia montevidensis,* are also present (10–20 cm, 4–8%). Grasses are represented by *Bromus catharticus* and *Stipa ichu.* Bryophytes and lichens are common. Noteworthy is the presence of the 1–1.6 m high resinous shrubs of *Aristeguietia ballii* with a cover of 10–20% growing abundantly in rock crevices. This species has aromatic dark green leaves and pink flowers. In this association 41 vascular plant species have been noted.

Character and differential species: Character species are *Asplenium peruvianum, Campyloneurum amphostenon*, *Echeveria peruviana, Elaphoglossum minutum* and *Festuca weberbaueri.* Differential species within the alliance are *Achyrocline alata, A. ramosissima, Aristeguietia ballii, Asplenium peruvianum, Bartsia peruviana, Bowlesia lobata, Calceolaria lobata, Chersodoma jodopappa, Hypochaeris meyeniana, Paronychia andina, Spergularia fasciculata, Vasquezia oppositifolia* and *Viguiera procumbens.* The character species of the alliance *Neowerdermannia peruviana* has its highest presence in this association. The same applies for *Senecio sublutescens* and *Woodsia montevidensis* which are character species of the class and order.

Ecology and distribution: The crevices and cracks of the steep rock slopes contain soil deposits of silty clay particles with iron oxides. They can be found at an altitude of 3950–4100 m on S and W. facing, steep (60–80°) rocky slopes on the east side of the Paltuture River at the boundary between the Ubinas and Ichuña districts. The vegeteation has a higher cover and the species diversity is higher than in other chasmophytic units.

Alliance: ***Hypochaerido mucidae-Loricarion graveolentis*** (Appendix A1, col. 4–6; A2, col. 3–6; Fig. 4, 5)

18 Treated as Satureja boliviana in chapter 2 and 6. Clinopodium bolivianum is an accepted name and synonym of Satureja boliviana according to The Plant List (2010).

Physiognomy, composition and distribution: This alliance combines the vegetation growing on shallow soils from rock plateaus and rock crevices in the north of Moquegua, South Peru. One of the characteristic species, *Hypochaeris mucida*, is almost restricted to this geographical region (but is expected to occur also in the south of Puno department and probably in SW Bolivia) (Brako & Zarucchi 1993, Montesinos-Tubée 2012a, Tropicos 2014). Between 4000 to 4500 m this species has an extensive distribution on the slopes of the tributaries and dry ravines of the upper Tambo and Ichuña Rivers. The other species, *Loricaria graveolens*, is an erect or hanging dwarf shrub with scale-like leaves, pubescent and strongly aromatic. This species inhabits rocky slopes, crevices or grows on superficial soils; its geographical distribution comprises central and southern Peru (Brako & Zarucchi 1993, Tropicos 2014).
Character and differential species: Character species are: *Belloa kunthiana, Hypochaeris mucida* and *Loricaria graveolens.* Species such as *Bomarea dulcis, Calamagrostis vicunarum, Cerastium subspicatum* and *Cheilanthes pilosa* are differential against the *Argyrochosmo niveae-Neowerdermannion peruvianae*. The absence of *Salpichroa glandulosa* and *Stipa ichu* is characteristic.
Except for the common *Valeriana nivalis,* we found little floristic similarity with the *Chersodomo diclinae-Valerianetum nivalis* occurring in Tacna and Puno Regions (Galán de Mera et al. 2003). The *Hypochaerido mucidae-Loricarion graveolentis* comprises the vegetation from shallow soils and rock crevices at higher altitudes; it is dominated by the endemic ground rosette plant *Hypochaeris mucida,* a biannual herb with dense pubescence on both surfaces of the leaves. The presence of this species is restricted to the south of Puno (Brako & Zarucchi 1993) and the north of Moquegua department (Montesinos-Tubée 2011a). In the Moquegua region it is especially common on rocky slopes, where it is restricted to rock crevices and shallow soils. Here, in association with species such as *Loricaria graveolens,* it forms dense and extensive communities that do not occur in grasslands. The new association *Paronychio ubinensis-Hypochaeridetum mucidae* is characterized by the endemic *Paronychia ubinensis* (Montesinos-Tubée 2013a), which grows on shallow soils where several endemics have been found, especially from the *Caryophyllaceae*.

4. *Hypochaerido mucidae-Valerianetum nivalis* (Appendix A1, col. 4; A2, col. 4)
Physiognomy and composition: Association with low density and diversity of dwarf shrubs, annual herbs, few grasses and ferns. Characteristic are the pubescent-leaved shrubs of *Senecio* sp. (# 3729) (0.5–1.5 m, cover 5–10%) hanging from rock crevices. The relatively dense, 1–20 cm high layer of annual herbs and dwarf shrubs is dominated by *Belloa piptolepis, Cerastium subspicatum, Gnaphalium polium, Hypochaeris mucida, Paronychia andina, Peperomia scutellaefolia, Solanum bukasovii* and *Valeriana nivalis.* The abundance of the grass *Nassella inconspicua* in combination with the ferns *Cheilanthes pruinata* and *Woodsia montevidensis* is diagnostic.

Character and differential species: Character species are *Valeriana nivalis, Gnaphalium polium, Senecio* sp. (# 3729) and *Perezia ciliosa.* Differential species within the alliance are *Solanum bukasovii, Bowlesia lobata, Valeriana interrupta, Cheilanthes pruinata* and *Woodsia montevidensis. Bomarea dulcis,* a characteristic species of the order, also has its highest frequency in this association.
Ecology and distribution: This association is widely distributed at 4050–4200 m, growing in crevices, cracks and shallow soils of the dry rocky ravines in the northwest of the upper Tambo River catchment in the Ubinas district. The vegetation of this association extends over convex, wind-exposed slopes with an inclination of 10° to almost 80°. Soils are variable in depth (5–30 cm) and their texture is predominantly clayey-silty.

5. *Paronychio ubinensis-Hypochaeridetum mucidae* (Appendix A1, col. 5; A2, col. 5; Fig. 5)
Physiognomy and composition: Association with variable frequency of annual herbs, dwarf shrubs and grasses. It consists of 1–4 cm tall acaulescent herbs and dwarf shrubs with a cover of 20–30% in combination with the 10–30 cm high shrub *Loricaria graveolens* with a cover of 10–15 % and a layer of grasses that reach a height of up to 1 m with 8–12% cover. Among the dwarf shrub layer species with substantial cover are *Belloa piptolepis, B. kunthiana*, *Lupinus ananeanus, Nototriche foetida, Paronychia andina, P. ubinensis* and *Wahlenbergia peruviana.* The herb layer is dominated by *Cardionema ramosissimum, Plantago sericea* var. *lanuginosa, Spergularia andina* and *Valeriana radicata.* The grass layer is composed of *Bromus catharticus, Calamagrostis vicunarum, Nassella inconspicua* with relatively low cover and *Luzula racemosa* with 10–30 cm height and cover of 2–4%.
Character and differential species: Character species are *Cerastium* sp. (# 3728), *Chaetanthera peruviana Paronychia ubinensis* and *Spergularia andina.* Differentials within the alliance are *Bartsia crenoloba, Cardionema ramosissimum, Cyperus seslerioides Galium corymbosum, Hypochaeris meyeniana, Lupinus ananeanus, Muhlenbergia peruviana* and *Plantago sericea* var. *lanuginosa. Nototriche foetida* can be considered character species of the *Loricario graveolentis-Pycnophylletum mollis*, an association still to be described for the *Hypochaerido mucidae-Loricarion graveolentis* (Montesinos-Tubée et al., unpubl.).
Ecology and distribution: This association is generally found near grasslands and steep rock formations, at edges of slopes or on hilltops. It grows at altitudes of 4120–4300 m, on slopes with an inclination of 5–40°. The soils contain stones and are of grayish color in the surface layer. These communities can be found on the rocky slopes of the upper Tambo River valley, in the Yunga and Ubinas districts.

6. *Hypochaerido mucidae-Paronychietum muschleri* (Appendix A1, col. 6; A2, col. 6)
Physiognomy and composition: Chasmophyte vegetation with 80–120 cm tall shrubs hanging from the rock crevices and a cover of 10–20% among Dwarf rosettes and annual herbs cover 10–15% of the surface. The surface is further covered to 4–8% by grasses 60–100 cm tall. The ground layer is dominated by several herbs and dwarf rosettes such as *Belloa kunthiana*, *B. piptolepis, B. schultzii, Cerastium* sp. (# 3728)*, Hieracium streptochaetum, Hypochaeris mucida, Paronychia muschleri* and *Peperomia scutellaefolia.* The grass layer is composed of *Bromus catharticus* and *Calamagrostis vicunarum.* Further, 10–20 cm tall ferns (*Cheilanthes pilosa* and *Polystichum orbiculatum*) are also present and cover 4–8% of the surface. Bryophytes and lichens are abundant on rock surfaces.
Character and differential species: Character species are *Paronychia muschleri* and an as yet unidentified species of *Draba* (coll. no. 3186). It is further differentiated against the other associations of this alliance by the species characteristic of the order, *Cheilanthes pilosa* and *Senecio sublutescens.*
Ecology and distribution: The vegetation of this association grows on steep metamorphic rock surfaces, in fissures and cracks frequently filled with clayey-silty soil deposits. It occurs at 4000–4300 m in the steep ravines of the Yunga district. At its lower limit the *Hypochaerido mucidae-Paronychietum muschleri* is in contact with the *Baccharido tricuneatae-Puyetum raimondii.* It also grows above the upper boundary of the chasmophyte community of *Plantagini sericeae-Plazietum daphnoidis*. In addition, it borders the azonal vegetation of *Plantaginetalia tubulosae* on humid ground.

7. Community of *Asplenium triphyllum* and *Polystichum orbiculatum* (Appendix A1, col. 7)
Physiognomy and composition: The vegetation is characterized by the relatively high density of shrubs, hanging with sprawling stems, characteristic of which are *Bomarea dulcis, Loricaria graveolens, Ribes brachybothrys* and *Senecio sublutescens*. The edges are dominated by *Calceolaria lobata, Cerastium subspicatum* and *Stellaria weddellii* 10–15 cm tall and reaching 1–2% cover. Ferns are more abundant than in the other chasmophyte communities. *Asplenium triphyllum, Cystopteris fragilis, Polystichum orbiculatum* and *Woodsia montevidensis* occur with 2–4% cover. A grass layer is hardly present and only represented by *Bromus catharticus*, 60–80 cm tall and with 2% cover. Bryophytes and lichens are abundant on the rock surfaces.
Character and differential species: It is characterized by the combination of *Asplenium triphyllum, Stellaria weddellii, Polystichum orbiculatum* and, with low presence, also *Descurainia athrocarpa.* As there are no own character species this plant community is ranked only to the level of order.
Ecology and distribution: The vegetation occurs on humid rocky edges of caves and caverns, frequently with water seeping out of the rocks on slopes with about 70–90° inclination. It occurs in contact with the vegetation of the *Calamagrostietea vicunarum.*

The sites studied are on steep slopes of the Yunga district and occur at an altitude of 4500 m. The community is restricted to rock sehlters and caverns and probably occurs at other altitudes and in other regions as well.

Grassland and shrubland vegetation of the puna (*Calamagrostietea vicunarum*)

The vegetation of the ***Calamagrostietea vicunarum*** grows on clay and loamy clay (rarely on sand) on rocky slopes, plateaus and hills at 3800–4500 m. In the Andean regions of northern Moquegua, it is in contact with scrubland of the class *Echinopsio-Proustietea cuneifoliae* and upslope with various units of the *Anthochloo-Dielsiochloetea*. In rocky areas the *Calamagrostietea vicunarum* is in direct contact with the *Argyrochosmetea niveae*. The diagnostic species of the class is *Calamagrostis vicunarum.*
As *Deyeuxia vicunarum* and *Deyeuxia minima* are considered synonyms of *Calamagrostis vicunarum* and *Calamagrostis minima,* respectively (Tropicos 2014, The Plant List 2010), we recommend to retain the names *Calamagrostietea vicunarum* Rivas-Martínez & Tovar 1982 and *Calamagrostion minimae* Rivas-Martínez & Tovar 1982, in contrast to the suggestion of Galán de Mera et al. (2014).
The order ***Parastrephietalia quadrangularis*** combines the puna grasslands, the *Parastrephia* ('tolares') communities and scrublands proper of the central and southern arid and semi-arid Andes occupying the supratropical and orotropical bioclimates (Navarro 1993). Its area extends over southwest Peru, west of Bolivia, northwest Argentina and northwest Chile. The following are character species of the order: *Baccharis tricuneata, Chersodoma jodopappa, Cumulopuntia boliviana* subsp. *ignescens, Ephedra rupestris, Festuca dolichophylla, Gomphrena meyeniana, Parastrephia quadrangularis, Plantago sericea* var. *lanuginosa* and *Tetraglochin cristatum.*

Alliance: ***Azorello compactae-Festucion orthophyllae*** (Appendix A1, col. 8–14; Fig. 5–7)
Physiognomy and composition: The alliance is documented here by 89 relevés containing 156 plant species. The communities described are characterized by the high presence and cover of the resinous composite shrub *Parastrephia quadrangularis* and the spiny *Tetraglochin cristatum*, together with the constant species *Stipa ichu.*
Character and differential species: Character species for the alliance: *Belloa longifolia, Clinopodium bolivianum, Conyza deserticola, Geranium sessiliflorum, Lepechinia meyenii, Lobivia maximiliana, Oxalis calachaccensis, Philibertia lysimachioides, Tarasa nototrichoides* and *Wahlenbergia peruviana*.
Within the *Azorello compactae-Festucion orthophyllae* we distinguish three associations and two rankless plant communities. One of the associations, the *Baccharido tricuneatae-Puyetum raimondii*, has been subdivided into four subassociations.
Ecology and distribution: This alliance dominates large areas in the puna of northern Moquegua and also occurs in the Arequipa, Tacna and Puno departments. In our study

region, it occurs at an altitude of 4000–4500 m, where *Festuca dolichophylla, Parastrephia quadrangularis, Stipa ichu* and *Tetraglochin cristatum* dominate the landscape. These dry to subhumid grasslands grow on slopes with inclinations of 10–40°, without preference for a particular slope aspect. Grazing intensity varies; a few types of grassland are heavily grazed while others can be considered to be ungrazed.

The *Azorello compactae-Festucion orthophyllae* represents the large tracts of puna grasslands in South Peru, in the Moquegua region where *Festuca dolichophylla, Parastrephia quadrangularis* and *Tetraglochin cristatum* are common. *Festuca dolichophylla* is the tussock grass that dominates the puna grasslands of Moquegua in association with *Parastrephia quadrangularis.* The latter species is replaced by *Parastrephia lucida* in the superpuna grasslands above 4500 m a.s.l. The tussock grass distribution is in agreement with Navarro & Ferreira (2004), who recorded *Festuca dolichophylla* in the subhumid puna of Bolivia at 3500–4000 m and 4500 m and *Festuca orthophylla* at higher altitudes in the superpuna and subnival puna. Above 4500 m *Festuca orthophylla* co-occurred with cushion plants such as *Azorella* and *Pycnophyllum.* We found the same co-occurrence in the Andes of north Moquegua and presume that the species also occurs in the high Andes of Arequipa and Tacna.

8. *Baccharido tricuneatae-Puyetum raimondii* (Appendix A1, col. 8–11; A2, col. 8–11; Fig. 5–6)

Physiognomy and composition: The association is characterized by the co-occurrence, presence and cover of the giant bromeliad *Puya raimondii* and the shrub *Baccharis tricuneata* as described by Galán de Mera et al. (2009). In our study the *Baccharido tricuneatae-Puyetum raimondii* appears to be notably species-rich: we found 131 plant species in 51 relevés.

Character and differential species: Character species are *Alstroemeria pygmaea, Baccharis genistelloides, Euphorbia huanchahana, Lupinus paruroensis, Mutisia orbignyana, Puya raimondii, Lophopappus tarapacanus* and *Solanum fragile.* In addition, species such as *Achyrocline ramosissima, Calceolaria inamoena, C. lobata, Paronychia setigera, Solanum bukasovii* and *Valeriana interrupta* are differential against the other associations and communities within the alliance.

Ecology and distribution: The *Baccharido tricuneatae-Puyetum raimondii*, with its stands of giant rosettes, is widespread and presumably restricted to the Andean slopes of southern Peru. The communities develop on steep, subhumid scree slopes in which several species of the *Argyrochosmetea niveae* also occur. When *Puya raimondii* establishes, the scree becomes stabilized. The subassociations differ greatly in slope aspect percentage of rock cover and grazing pressure. The importance of the conservation of the endangered giant bromeliad *Puya raimondii* is widely recognized (Lambe 2009).

Figure 2. *Plantagini sericeae-Plazietum daphnoidis* (A) on the rocky west-facing slopes of the upper Tambo River (3750–4000 m) within *Echinopsio-Proustietea* Montesinos, Cleef & Sýkora (B); (C) represents the *Plantaginetalia tubulosae* Gutte (*Plantagini rigidae-Distichietea muscoidis* Rivas-Martínez & Tovar).

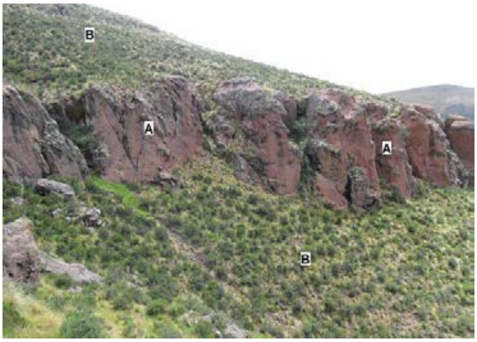

Figure 3. *Phacelio secundae-Ribesetum brachybothryos* (A) and *Sisyrinchio rigidifolii-Parastrephietum quadrangularis* (B) at 4000 m near the Ichuña River, close to Tolapampa town.

Figure 4. *Hypochaeris mucida* var. *integrifolia* at 4300 m in Sura, Yunga district.

Figure 5. Overview of the steep rocky outcrops in the Yunga district where (A) *lupinetosum cuzcensis* (*Baccharido tricuneatae-Puyetum raimondii*) occurs, (B) *Paronychio ubinensis-Hypochaeridetum mucidae,* at 4400 m and (C) downstream of the Tambo River where the class *Echinopsio-Proustietea cuneifoliae* occurs (3500 m) in the Ubinas district.

According to Gutte (1986), Galán de Mera et al. (2009) and this study, *Puya raimondii* is distributed between 3800–4500 m but its range is expected to extend to even higher altitudes.

The *Senecioni nutantis-Parastrephietum quadrangularis* described by Galán de Mera et al. (2011b) shares affinities with the *Baccharido tricuneatae-Puyetum raimondii lupinetosum cuzcensis* because of the presence of *Senecio nutans* and *Parastrephia quadrangularis.* It differs greatly in species composition, however, because of the absence of *Festuca orthophylla, Azorella compacta, Senecio spinosus, Lupinus saxatilis, Polylepis rugulosa* among other species with lower presence. In addition, it is distinct in its distribution which comprises the Condesuyos province in the Arequipa region.

8.1 *senecionetosum ferreyrae* (Appendix A1, col. 8; A2, col. 8)

Physiognomy and composition: Grassland vegetation with high density and diversity of rosette shrubs, tussock grasses and annual herbs. *Puya raimondii,* a species with 2 to 3.5 (4) m tall stem rosettes with spiny, coriaceous leaves and with huge inflorescences can attain a height of 9–10 m. Asteraceous shrubs together with tussock grasses dominate a 50–100 cm high dense shrub layer. *Puya raimondii* is particularly prominent in the upper layer, together with a few other species of shrubs such as *Ageratina azangaroensis, Baccharis tricuneata, Chersodoma jodopappa, Clinopodium bolivianum, Escallonia myrtilloides, Mutisia orbignyana, Parastrephia quadrangularis, Senecio ferreyrae* and *S. sublutescens.* In the intermediate layer, *Puya raimondii* grows together with *Festuca dolichophylla* and *Stipa ichu*. The cacti *Cumulopuntia boliviana* subsp. *ignescens* and *Lobivia maximiliana* are present in the ground layer. More frequent species in the ground layer are *Alstroemeria pygmaea, Belloa piptolepis, Cardionema ramosissimum, Cyperus seslerioides, Euphorbia huanchahana, Galium corymbosum, Hypochaeris chillensis* and *Oxalis megalorrhiza*. The ferns *Cheilanthes pruinata, Ch. pilosa* and *Woodsia montevidensis* are present as well. This subassociation is extremely species-rich, with 96 vascular plant species in 15 relevés.
Differential species are *Ageratina azangaroensis, Bomarea involucrosa, Gomphrena meyeniana*, *Loricaria graveolens, Perezia pungens, Senecio ferreyrae, Stevia macbridei,* and with low frequency also *Aphanes andicola, Escallonia myrtilloides, Solanum chamaesarachidium* and *Triniochloa stipoides. A. andicola* and *S. chamaesarachidium* have been found only in this subassociation, albeit with very low frequency.

Ecology and distribution: The subassociation can be found either as extensive vegetation or in small stands. It grows at 3850–4150 m, on rocky slopes with inclinations between 10 and almost 55 degrees. Stands occur in the areas of Yunga and Tassa, upper Tambo River. The *senecionetosum ferreyrae* is in contact with the chasmophytic association *Hypochaerido mucidae-Paronychietum muschleri*.

8.2. *ageratinetosum sternbergianae* (Appendix A1, col. 9; A2, col. 9)

Physiognomy and composition: Grassland vegetation with a great abundance of shrubs with dominance of tussock grasses and annual herbs. The *Puya raimondii* rosettes cover 20–40% of the surface. A layer of tall tussock grasses up to 80–140 cm height covers 20–30%. Additionally, shrubs and dwarf shrubs attain 40–60 cm in height; 10–20 cm tall annual herbs and ferns cover 10–15%. In the upper layer, the dominance of *Puya raimondii* is noteworthy, together with other species such as *Baccharis tricuneata, Chersodoma jodopappa, Parastrephia quadrangularis, Ribes brachybothrys* and *Clinopodium bolivianum.* The cacti are represented by *Cumulopuntia boliviana* subsp. *ignescens* and *Lobivia maximiliana.* Herbs include species such as *Cardionema ramosissimum, Cyperus* *seslerioides, Galium corymbosum, Hieracium streptochoetum, Hypochaeris chillensis, Tagetes multiflora, Valeriana interrupta* and dwarf shrubs by *Achyrocline ramosissima, Conyza deserticola* and *Spergularia fasciculata.* Dominant grasses are *Bromus catharticus, Nassella inconspicua, Festuca dolichophylla* and *Stipa ichu.* This subassociation is very species-rich, having 96 vascular species in 19 relevés.

Differential species: This subassociation is characterized by *Ageratina sternbergiana, Calandrinia acaulis, Cheilanthes pilosa, Facelis plumosa, Ribes brachybothrys, Stevia mandonii* and *Weberbauera peruviana,* and, but with low cover only, *Bougueria nubicola, Cheilanthes arequipensis* and *Spergularia fasciculata*.

Ecology and distribution: The subassociation extends over grasslands and rocky crevices along the Ichuña River between 3850 and 4250 m. It is present on convex slopes with inclinations of 10–80°. The soils are comparatively deep, 20–60 cm, with clay in grasslands and with silty clay in rock crevices.

8.3. *lupinetosum cuzcensis* (Appendix A1, col. 10; A2, col. 10; Figure 5)

Physiognomy and composition: Dense grassland vegetation, with a variable frequency of spiny rosettes and tussock grasses. The vegetation is composed of three layers: a layer of 2–3.5 (4) m tall leptophyllous shrubs including spiny rosettes, with a cover of 20–35% and an inflorescence of 4 m height; a layer of tall tussock grasses that reach 1–1.3 m with 40–50% cover; and a ground layer consisting of annual herbs and some bryophytes covering 10–15%. Among the shrub and dwarf shrub species with high cover are *Baccharis tricuneata, Lupinus cuzcensis, L. paruroensis, Parastrephia quadrangularis, Puya raimondii, Senecio nutans* and *Tetraglochin cristatum.* The cactus species *Cumulopuntia boliviana* subsp. *ignescens* is present with 4–6% cover. Among the grasses are *Festuca dolichophylla* and *Stipa ichu* in the shrub layer; in the herb layer are *Calamagrostis vicunarum, Galium corymbosum, Gnaphalium dombeyanum, Hieracium streptochaetum, Hypochaeris meyeniana, Microsteris gracilis, Muhlenbergia peruviana, Olsynium junceum, Oxalis nubigena* and *Plantago sericea* var. *lanuginosa.* Ferns are almost absent.

Differential species: *Calamagrostis vicunarum, Calamagrostis violacea, Gnaphalium dombeyanum, Lupinus cuzcensis, Lupinus ananeanus, Lupinus* sp. 1 (# 3713), *Olsynium junceum, Ourisia muscosa, Oxalis nubigena, Senecio nutans* and *Valeriana radicata.*

Ecology and distribution: The *Puya raimondii* grasslands belonging to the *lupinetosum cuzcensis* occur at an altitude between 4400–4500 m, on slopes of 20–30°, in the Ubinas, Yunga and Ichuña districts. In this subassociation the spiny rosettes of *Puya raimondii* reach their altitudinal limit, with inflorescences up to 4 m tall.

8.4. *calamagrostietosum heterophyllae* (Appendix A1, col. 11; A2, col. 11)

Physiognomy and composition: Grassland vegetation with low density and diversity of shrubs. The 2–3 (10) m tall rosettes of *Puya raimondii* cover 20–30%. A 40–80 cm high, dense grass layer is present, dominated by tussock grasses and small shrubs. In

Figure 6. The giant bromeliad Puya raimondii (ca. 12 m) occurring in the ***senecionetosum ferreyrae*** (***Baccharido tricuneatae-Puyetum raimondii***), Punku site, Tassa locality, Ubinas district (4030 m).

the intermediate layer, the dominance of *Baccharis tricuneata, Chersodoma jodopappa, Lupinus paruroensis* and *Parastrephia quadrangularis* is characteristic. The ground layer is dominated by *Alstroemeria pygmaea, Bowlesia lobata, Cyperus seslerioides, Galium corymbosum, Gilia laciniata, Hieracium streptochaetum, Hypochaeris chillensis, Lepechinia meyenii, Microsteris gracilis* and *Tarasa nototrichoides. Festuca dolichophylla* is absent and instead a variety of other grasses occur, such as *Calamagrostis heterophylla, Nassella inconspicua, Poa gymnantha* and *Stipa ichu.* A total of 51 vascular species have been recorded in seven relevés.

Differential species: It is characterized by *Achyrocline ramosissima, Alstroemeria pygmaea, Calamagrostis heterophylla, Gamochaeta purpurea, Gilia laciniata Laennecia artemisioides, Lepechinia meyenii, Poa gymnantha, Stipa obtuse* and *Viola micranthella.*

Ecology and distribution: The *calamagrostietosum heterophyllae* covers grassland slopes with an inclination of 20–40° and a NE exposure, at an altitude of 4100–4200 m, in the northwest area of the upper Tambo River catchment, in the Ubinas district. As there are fewer rocks and stones, the cover of the vegetation is very high. Soils are predominantly clayey and soil depth varies from 20–50 cm.

9. *Sisyrinchio rigidifolii-Parastrephietum quadrangularis* (Appendix A1, col. 12; A2, col. 12)

Physiognomy and composition: Grassland vegetation with a cover of about 70–80% and with a great abundance of shrubs, dwarf shrubs, tussock grasses, annual herbs and ferns. The 30–50 cm tall *Sisyrinchium rigidifolium* layer covers 4–6%. The upper layer is dominated by the tussock grass *Stipa ichu* (70–100 cm tall) and the resinous shrub *Parastrephia quadrangularis* (60–90 cm), with a combined cover of 40%. The 1–1.6 (2) m tall *Mutisia orbignyana* (4% cover), is represented in only four relevés out of twenty. The dominant grass in this association is *Stipa ichu.* Small shrubs and dwarf shrubs (*Baccharis tricuneata, Tetraglochin cristatum*) reach 30–60 cm with a cover of 6–8%. The 10–15 cm tall cushion cactus *Cumulopuntia boliviana* subsp. *ignescens* is constant and covers between 4 and 6%. Rosettes and annual herbs such as *Belloa piptolepis, Bowlesia lobata, Caiophora chuquitensis, Conyza deserticola, Galium corymbosum, Gilia laciniata, Hypochaeris chillensis, Lepechinia meyenii, Oxalis megalorrhiza, Perezia pungens* and *Silene genovevae* dominate the ground layer. Ferns are dominated by the 10–20 cm tall *Cheilanthes pruinata* with a cover of 4–6%.

Character and differential species: Character species are *Sisyrinchium rigidifolium* and *Caiophora chuquitensis* and, with low presence, also *Bartsia melampyroides* and *Oenothera nana* and *Astragalus arequipensis, Hedeoma mandoniana, Lobivia* sp. (Image 0468, 15/04/2012), *Ophioglossum crotalophoroides, Perezia sublyrata.* It is further differentiated by *Paronychia muschleri, Plantago* sp. (Image 0397, 15/04/2012), *Senecio evacoides, Silene genovevae* and *Valeriana coarctata.*

Ecology and distribution: The *Sisyrinchio-Parastrephietum* extends over large areas on slopes at the edges of ravines of the Ichuña River between 3950 and 4200 m. The majority of slopes face N, E and S with an inclination of 25–55°. In general, the soils are 30–60 cm deep, with clayey texture and red-purple color. This association is in contact with the chasmophytic *Phacelio secundae-Ribesetum brachybothryos*.

10. Community of *Misbrookea strigosissima* and *Stipa ichu* (Appendix A1, col. 13; Figure 7)

Physiognomy and composition: Grassland vegetation with a great abundance of annual herbs with rosettes, tussock grasses and dwarf shrubs and a cover of about 65–75%. The upper layer is dominated by the tussock grass *Stipa ichu* (80–120 cm tall) and the resinous shrubs *Parastrephia quadrangularis* (60–80 cm) and *Baccharis tricuneata*, attaining 30% cover. The absence of *Chersodoma jodopappa,* the tussock *Festuca dolichophylla* and the cushion cactus *Cumulopuntia boliviana* subsp. *ignescens* are characteristic. The 10–20 cm tall dwarf shrubs *Ephedra rupestris* and *Tetraglochin cristatum* cover 4–6%. The ground layer (20% cover) is dominated by rosettes and annual herbs such as *Belloa longifolia, B. piptolepis, Calamagrostis vicunarum, Geranium sessiliflorum, Gomphrena meyeniana, Hypochaeris meyeniana, Misbrookea strigosissima, Muhlenbergia peruviana, Oxalis calachaccensis, Plantago sericea* var. *lanuginosa* and *Stenomesson* sp. (# 3871). Several herbs such as *Crassula connata, Geranium sessiliflorum, Belloa* sp.1 (# 3824), *Misbrookea strigosissima* and *Senecio rhizocephalus* on sites with accumulated manure indicates intensive grazing. Ferns are absent.

Character and differential species: This community is characterized by *Misbrookea strigosissima, Stenomesson* sp. (# 3871), *Senecio rhizocephalus, Belloa* sp.1 (# 3824) and *Perezia coerulescens,* and further weakly differentiated within the alliance by *Laennecia artemisioides* and *Gomphrena meyeniana.*

Ecology and distribution: The community extends as grassland over large areas on slopes in the north of the Ichuña River at an altitude of 4250–4500 m and can also be found in the upper grasslands of the Yunga district. The slopes mainly face NE with an inclination of about 35°. In general the red to gray clayey soils are 30–60 cm deep. The community is in contact with the chasmophyte vegetation of the *Phacelio secundae-Ribesetum brachybothryos*.

At higher altitude on less steep terrain, grazing by sheep, llamas and alpacas is much more common. The long history of grazing and manuring has favored the presence of the tussocks of *Stipu ichu*, with small rosettes such as *Misbrookea strigosissima* and *Plagiobothrys humilis*. As happens in the high Ecuadorian and Colombian páramos or, at high altitude (4100–4300 m) azonal cushion communities appear on zonal slopes before the transition to superpáramo. They are mainly of *Plantago rigida* and with less presence of *Azorella multifida*, and they replace the bunch grassland (e.g. Cuatrecasas 1958; Harling 1979). Increased precipitation and persistent mist seem responsible

(Salamanca et al. 2003). The puna association (12) *Baccharido caespitosae-Azorelletum diapensioidis* seems a vicariant community in this context.

11. Community of *Plagiobothrys humilis* and *Stipa ichu* (Appendix A1, col. 14; Fig. 8)

Physiognomy and composition: Grassland vegetation with a high cover of tussock grasses (70–80%), but with a low diversity of dwarf shrubs and annual herbs. It is highly affected by grazing. The upper layer is dominated by the 80–130 cm tall tussock grass *Stipa ichu* covering 40–60% and the 50–70 cm tall resinous shrub *Parastrephia quadrangularis* with 10–12% cover. The dwarf shrub *Tetraglochin cristatum* covers 6–8% while the 8–15 cm tall cushion cactus *Cumulopuntia boliviana* subsp. *ignescens* covers 4–6%. Other shrubs are absent in these communities. The ground layer is dominated by rosettes and annual herbs such as *Arenaria* sp. (# 2272), *Belloa piptolepis, Geranium sessiliflorum, Plagiobothrys humilis* and *Urtica echinata.* The last three species indicate intensive grazing. This community is very species-poor: only 15 vascular plant species in 9 relevés.

Character and differential species: It is characterized by *Plagiobothrys humilis, Urtica echinata* and *Arenaria* sp. (# 2272).

Ecology and distribution: Intensively grazed by llamas and alpacas and extending over large areas on Coalaque Mountain (Ubinas district) at 4300–4500 m altitude on NE-facing slopes with an inclination of 15–30 °. In general the clayey soils are 30–60 cm deep.

Alliance: ***Calamagrostion minimae*** (Appendix A1, col. 15)

Physiognomy and composition: One community is described for this alliance characterized by the presence of cushion plants, dwarf shrubs, tussock grasses, annual grasses and herbs. The vegetation is defined by the high cover of the cushion umbellifer *Azorella diapensioides.*

Character and differential species: Character species is *Calandrinia acaulis.*

Ecology and distribution: Grassland puna known as *cesped de puna* formed by small herbs and ground rosettes with long root systems, mostly developing on open and uniform slopes with shallow soils. The alliance is known to occur in the highlands of Peru and Bolivia (Rivas-Martínez & Tovar 1982; Galán de Mera et al. 2014) below 4800 m.

12. *Baccharido caespitosae-Azorelletum diapensioidis* (Appendix A1, col. 15; A2, col. 15)

Physiognomy and composition: Grassland with high density and diversity of dwarf shrubs, cushions, grasses and annual herbs. Vegetation cover of about 50–60%. The 20–

40 (50) cm tall resinous shrubs of *Parastrephia quadrangularis* cover 15–20%. Cushions attain 10–15% of the total cover (mainly represented by *Azorella diapensioides*). A dense 60–80 cm tall grass layer is present, dominated by the grasses *Stipa ichu* with *Festuca dolichophylla.* The absence of *Nassella inconspicua* is characteristic. The dwarf shrub layer is dominated by *Baccharis tricuneata, Parastrephia quadrangularis* and *Tetraglochin cristatum.* The ground layer is mainly represented by *Arenaria digyna, Baccharis caespitosa, Belloa piptolepis, Brayopsis calycina, Calamagrostis curvula, C. vicunarum, Calandrinia acaulis, Gomphrena meyeniana, Muhlenbergia peruviana* and *Plantago sericea* var. *lanuginosa.* Ferns are almost absent. The presence of the cushion-forming *Pycnophyllum glomeratum* and *P. molle,* together with *Junellia minima* and *Senecio candollei* indicate the proximity of the association to the highland communities above 4500 m composed of dwarf shrubs, cushions, short grasses and some annuals. A total of 57 species have been recorded in 10 relevés.

Character and differential species: This community is characterized by *Azorella diapensioides, Baccharis caespitosa* and *Calamagrostis curvula,* and with low presence also of *Senecio humillimus, Sisyrinchium brevipes, Aa rosei, Oxalis eriolepis, Sisyrinchium jamesonii.* It is further differentiated by *Brayopsis calycina* and *Senecio candollei.*

Ecology and distribution: It develops at 4350–4470 m of altitude, covering the extensive grasslands on the slopes west of the upper Tambo River in the Ubinas district. Furthermore, it occurs on slopes with an inclination of 10–35° and a SW to SE exposure. Downslope the association is in contact with the *Baccharido tricuneatae-Puyetum raimondii senecionetosum ferreyrae* and upslope with different communities of the superpuna class *Anthochloo-Dielsiochloetea*.

The *Baccharido caespitosae-Azorelletum diapensioidis* differs greatly from the *Parastrephia lucidae-Festucetum orthophyllae azorelletosum diapensioidis* (Galán de Mera et al. 2003) because of the absence of tussock grasses and other elements of the puna. We have included the *Baccharido-Azorelletum* in the *Calamagrostion minimae* (Rivas-Martínez & Tovar 1982) because of the abundance of cushion plants such as *Azorella diapensioides* and the presence of small grasses such as *Calamagrostis curvula* (morphologically similar to *C. minima*), and the absence of many species characterizing the *Azorello-Festucion*. Seibert & Menhofer (1992) also mention *Azorella diapensioides-Calamagrostis brachyphylla* vegetation (*Calamagrostion minimae*) from the Cordillera de Apolobamba, Bolivia.

Gradients and zonation

The main gradient in species composition (DCA axis 1, Figure 9) was strongly correlated to rock cover (r= –0.69), slope (r= –0.62), vegetation cover (r= 0.62), grazing (r= 0.57) and manure (r= 0.53). The correlation between the second axis and environmental variables was insignificant.

The chasmophytic units on the left-hand side of the diagram were positively correlated with rock cover percentage and slope, but negatively with grazing, manure and vegetation cover. The *Puya*

Figure 7. Grassland slopes with the community of *Misbrookea strigosissima* and *Stipa ichu*, in Yanapuquio, near Condorwasi, Ichuña District (4350 m).

Figure 8. Grassland represented by *Baccharido caespitosae-Azorelletum diapensioidis* (*Calamagrostion minimae*) at Pirhuani-Rancho, near Tassa locality, at 4400 m

raimondii units were positively correlated with altitude, stone cover percentage, and pH. The grassland communities are correlated with grazing, manure, vegetation cover and species diversity but negatively correlated with rock cover percentage and slope angle. Finally, the *Baccharido caespitosae-Azorelletum diapensioidis* is positively correlated with altitude and negatively correlated with the cover of stones, and pH.
Rock cover is high in the chasmophytic units (Figure 10). It is also relatively high in two of the subassociations of the *Baccharido tricuneatae-Puyetum raimondii*: the *senecionetosum ferreyrae* and the *ageratinetosum sternbergianae*. The mean rock cover is only around 10% in the *lupinetosum cuzcensis* and the *calamagrostietosum heterophyllae*. On steep slopes the cover by stones is usually low, except sometimes (high standard deviation) in the chasmophyte association *Phacelio secundae-Ribesetum brachybothryos*. Within the *Baccharido tricuneatae-Puyetum raimondii* the mean cover of stones is highest in the *senecionetosum ferreyrae* and the *ageratinetosum sternbergianae*. In the grasslands it is generaly low, with the exception of the *Sisyrinchio rigidifolii-Parastrephietum quadrangularis*. Four of the chasmophyte associations occur on slopes steeper than 60° but in the case of the *Paronychio ubinensis-Hypochaeridetum mucidae*, the inclination is only 5–40°. As can be expected, vegetation cover is least on the steep, rocky cliffs with chasmophyte vegetation and highest for the *Baccharido tricuneatae-Puyetum raimondii* and the zonal puna grasslands.

Figure 11 shows the altitudinal distribution of the syntaxa described in this survey. The gray boxes represent the distribution as based on the present field survey and the boxes in dashed lines the expected distribution based on the co-occurrence of the following character species of the syntaxa distinguished (Montesinos-Tubée 2011a,b, 2012a, 2014a): *Plazia daphnoides* and *Plantago sericea; Phacelia secunda* and *Ribes brachybothrys; Neowerdermannia peruviana; Hypochaeris mucida* together with *Valeriana nivalis, Paronychia ubinensis* and *P. muschlerii; Asplenium triphyllum* and *Polystichum orbiculatum; Puya raimondii* with *Senecio ferreyrae, Ageratina sternbergiana, Lupinus*

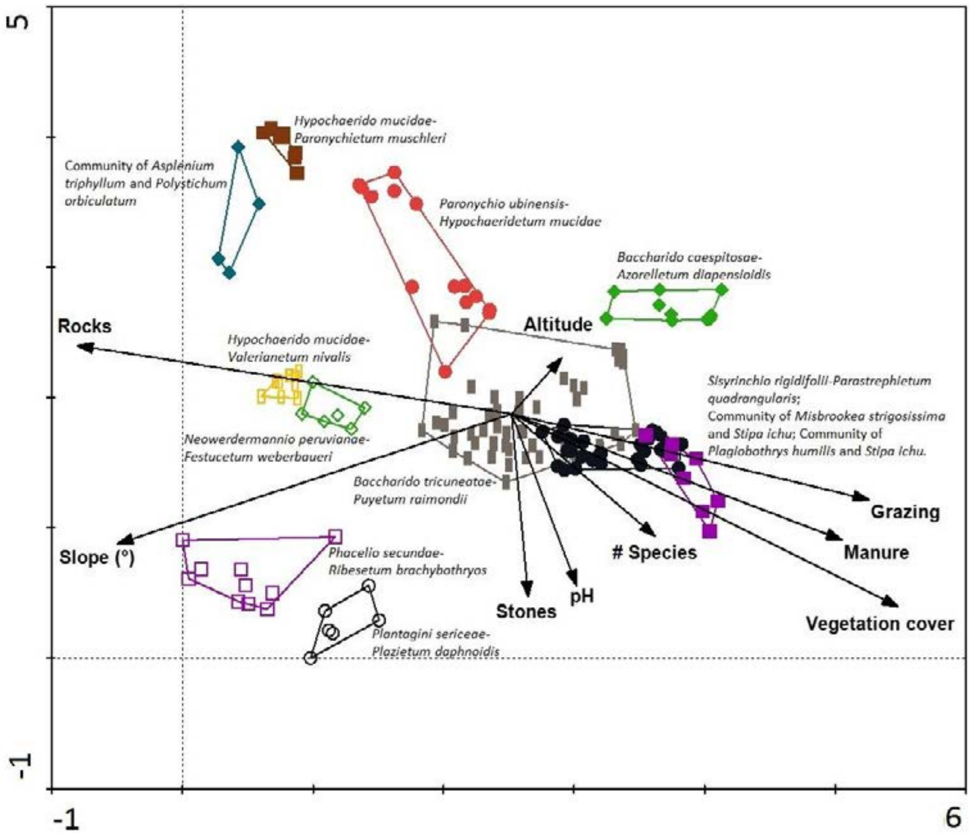

Figure 9. DCA analysis of 15 plant communities (weighted by presence class) and based on 210 plant species (see Appendix A1). The points representing the respective alliances, associations and communities are enveloped. Axis 1 eigenvalue is 0.512 and gradient length 4.131; Axis 2 eigenvalue is 0.367 and gradient length 4.064.

cuzcensis and *Calamagrostis heterophylla; Stipa ichu* with *Misbrookea strigosissima* and *Plagiobothrys humilis; Baccharis caespitosa* and *Azorella diapensioides.*

Floristic composition and affinity with previously published syntaxa

In total, 210 vascular plant species belonging to 131 genera and 52 families were recorded. The flora list of the total relevé dataset is dominated by composites (57 spp.), *Caryophyllaceae* (19 spp.), *Poaceae* (15 spp.), *Fabaceae* (11 spp.), *Brassicaceae* (9 spp.), *Pteridaceae* (7 spp.), *Cactaceae* (6 spp.), *Boraginaceae* and *Plantaginaceae* (5 spp. each). Shrubs (20–140 cm height) are represented by 42 species, the dwarf shrubs (2–20 cm height) by 39 species, and herbs by 95 species, including 18 species of grasses and sedges, 8 succulents and 15 fern species.

The floristic composition and diversity of the Andean grasslands of Moquegua change with altitude. Family composition shows the same trend as observed in the Andean

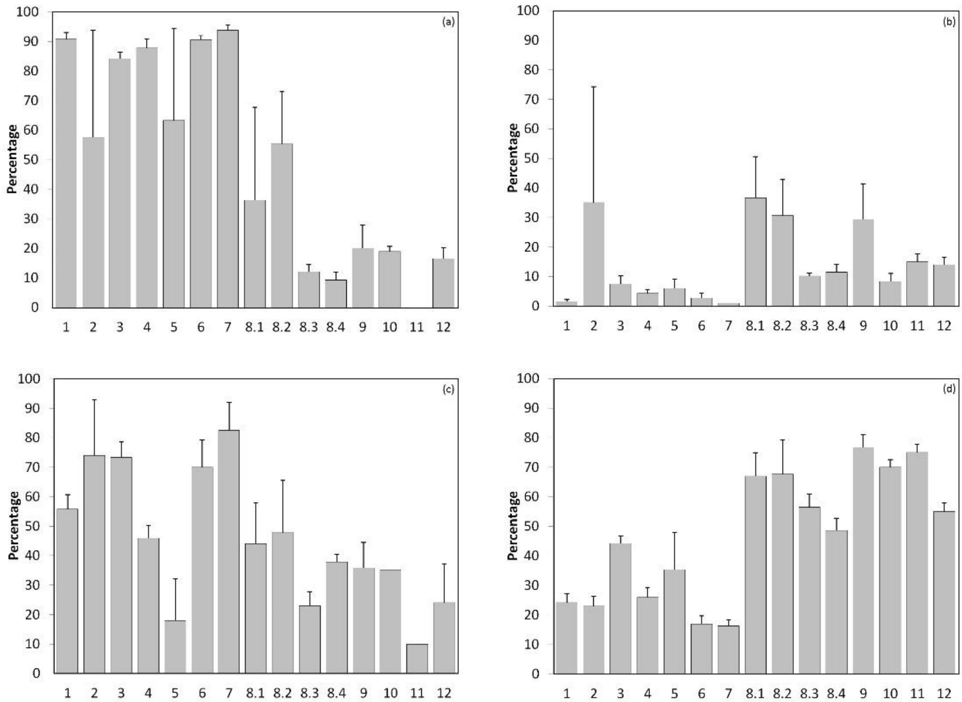

Figure 10. Bar charts showing the mean values (in per cent, except slope in degrees) with standard deviation for (a) rock cover, (b) stone cover, (c) slope inclination and (d) vegetation cover. (1) *Plantagini sericeae-Plazietum daphnoidis,* (2) *Phacelio secundae-Ribesetum brachybothryos,* (3) *Neowerdermannio peruvianae-Festucetum weberbaueri* (*Argyrochosmo niveae-Neowerdermannion peruvianae*)*,* (4) *Hypochaerido mucidae-Valerianetum nivalis,* (5) *Paronychio ubinensis-Hypochaeridetum mucidae,* (6) *Hypochaerido mucidae-Paronychietum muschleri* (*Hypochaerido mucidae-Loricarion graveolentis*), (7) *Asplenium triphyllum* and *Polystichum orbiculatum* (*Salpichroetalia glandulosae*), (8.1) *Baccharido tricuneatae-Puyetum raimondii senecionetosum ferreyrae*, (8.2) *ageratinetosum sternbergianae*, (8.3) *lupinetosum cuzcensis*, (8.4) *calamagrostietosum heterophyllae*, (9) *Sisyrinchio rigidifolii-Parastrephietum quadrangularis*, (10) Community of *Misbrookea strigosissima* and *Stipa ichu,* (11) Community of *Plagiobothrys humilis* and *Stipa ichu* (*Azorello compactae-Festucion orthophyllae*), (12) *Baccharido caespitosae-Azorelletum diapensioidis* (*Calamagrostion minimae*).

prepuna of Moquegua (Montesinos et al. 2012) where the composites dominate the environment.

Species diversity and composition also change along the altitudinal gradient, with variation caused by slope inclination. In the chasmophytic communities, species richness generally decreases with elevation; however, species richness was observed to increase locally between 3800 and 4200 m in the *Puya raimondii* communities, probably as a result of nursing effects. The high diversity of lichens and mosses reported by Gutte (1985) and Seibert & Menhofer (1991, 1992, 1993) is in accordance with our observations,

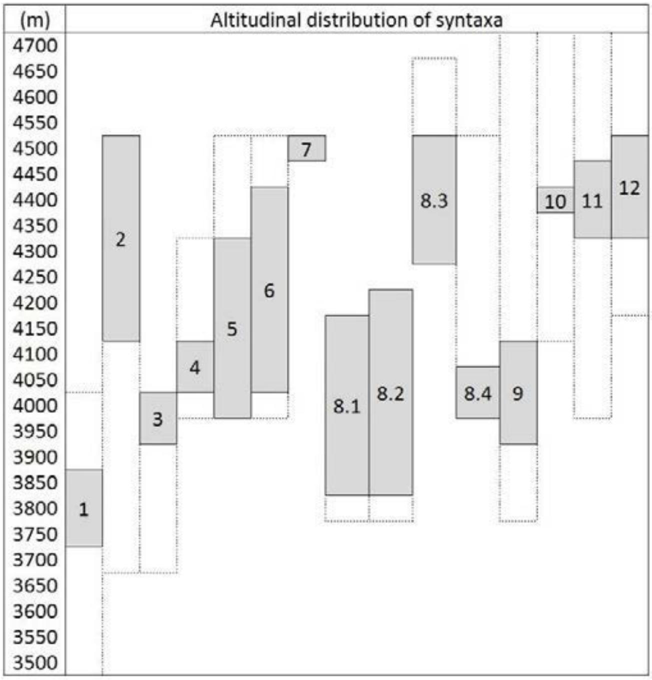

Figure 11. Altitudinal distribution of syntaxa (association, subassociation) and communities of the study area based on the relevés (solid lines) and references and field observations of diagnostic species elevation range (dashed lines) from Moquegua by the first author (Montesinos-Tubée 2011a,b, 2012a, 2014a).

although in our study these groups were not included in the phytosociological analysis. Substantial cover was observed only in the following associations with a prominent cover of pottiaceous mosses and lichens: *Neowerdermannio peruvianae-Festucetum weberbaueri, Hypochaerido mucidae-Paronychietum muschleri*, community of *Asplenium triphyllum* and *Polystichum orbiculatum* and *Baccharido tricuneatae-Puyetum raimondii senecionetosum ferreyrae*.

The communities and high ranked syntaxa of the Moquegua study area presented here were compared in a broader geographical context with similar vegetation types from other region of Peru, from Bolivia and Chile. A first run of the PC-ORD analysis resulted in a group of outliers of 45 vegetation units (see list in Appendix 6). These syntaxa have been excluded from the cluster analysis. The dendrogram (Fig. 12) was used to interpret the community structure by comparing related communities described in literature.

The chasmophytic units presented in this paper are clearly separated from the other communities. At the next level of similarity the data are divided into two groups: one group comprises the highland grasslands and some scrublands as described in literature, mainly from Southwest Bolivia, north of Chile and South Peru and the other the grasslands from Arequipa and Moquegua. The latter group is subdivided into a group with communities from the literature (16–20 in Fig. 12) and a group consisting of the *Baccharido tricuneatae-Puyetum raimondii* and of the grasslands presented in this study. The main difference is the characteristic and constant presence of *Festuca dolichophylla* in our communities by contrast with the presence of *Festuca orthophylla* in the first group.

In Fig. 12, at the highest level, the chasmophyte vegetation growing in rock crevices, fissures and shallow soils, the *Argyrochosmetea niveae* (1 to 7) is separated from the grassland vegetation of the *Calamagrostietea vicunarum* (8 to 15). At the next level, the *Argyrochosmo niveae-Neowerdermannion peruvianae* is separated from the *Loricarion graveolentis* (5–7). *Argyrochosmo niveae-Neowerdermannion peruvianae* includes the community of *Asplenium triphyllum* and *Polystichum orbiculatum*, which we decided to include at the order level only, since it is restricted to one cave community and does not represent the cave communities in general; this needs further investigation.

The *Puya raimondii* communities are grouped from 8 to 11; the association with *Sisyrinchium rigidifolium* is closely related to the *Puya raimondii* rocky environment since the association shares chasmophytic and grassland species. The communities of *Misbrookea strigosissima* and *Stipa ichu* and *Plagiobothrys humilis* and *Stipa ichu* (13 and 14) are closely related to the association of *Baccharido caespitosae-Azorelletum diapensioidis* (15), because they share companions, order and class species although belonging to the alliance *Azorello compactae-Festucion orthophyllae.*

Studies from north Chile (Lambrinos et al. 2006; Luebert & Gajardo 2000, 2005) and Bolivia (Seibert & Menhofer, 1991, 1992, 1993; Navarro 1993; Gutte 1995) were compared with our results and appear to differ significantly in species composition and zonation. Moreover the communities described by Montesinos et al. (2012) lack the presence of *Parastrephia quadrangularis, Tetraglochin cristatum* and the tussock grass *Festuca dolichophylla*, which are diagnostic elements of the puna.

We compared our communities with the alliance *Saturejion bolivianae* occurring in the Bolivian puna (Seibert & Menhofer 1993), which is distinct from the puna in the sites we studied in South Peru. The shrub *Clinopodium bolivianum* is present in our study area and considered an additional species of the order and alliance, since it is widely distributed in different highland environments in South Peru (Tropicos 2014). The difference in species composition between the *Saturejion bolivianae* and *Stipetalia ichu* (Gutte 1986), which is well represented in Central Peru, is considerable. The name Stipetalia ichu has not been used in recent years, because of the lack of phytosociological studies in Central Peru. The name *Parastrephietalia quadrangularis* has been introduced for South Peru (Navarro 1993): it comprises the highland units of the puna with grasslands and scrublands.

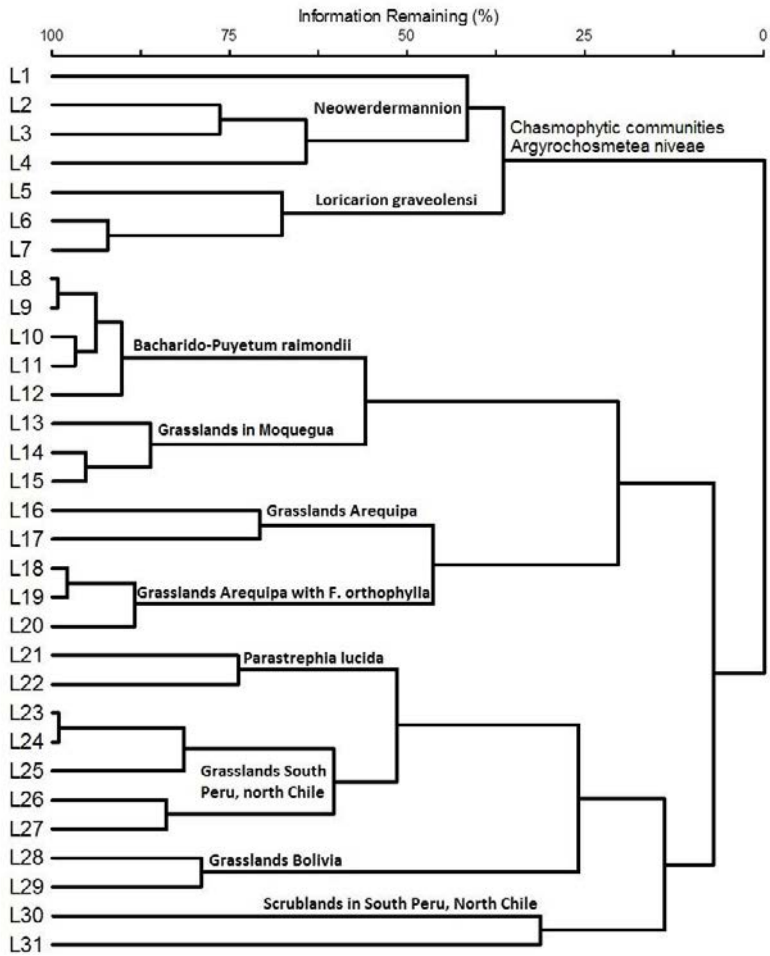

Figure 12. Dendrogram from Farthest Neighbor Clustering of 31 clusters (weighted by presence class) and based on 275 plant species (see methods and Appendix A1). The cluster numbers correspond to the plant communities 1–31 in the synoptic table (Appendix A1)

Concluding remarks

Our vegetation research in northern Moquegua (South Peru), an area not studied before, extends the knowledge of the syntaxonomy, floristic diversity and synecology of *Puya raimondii* stands, chasmophytic and grassland vegetation. It comprises two new alliances, eight new associations and four subassociations, representing an important basis for a future overview and synopsis of the Andean vegetation of South America. The vegetation studied in Moqequa appears to be floristically different from comparable vegetation in north Chile and Bolivia. Further research is needed, however, to study the relation with chasmophytic and grassland associations in the highlands of other mountainous regions in South America.

The present overview is also important as a reference and tool for nature conservation. Apart from the impressive giant bromeliad *Puya raimondii,* many other endemic species are found in the newly described syntaxa, increasing the need for conservation schemes and measures. In recent years, the puna grasslands and *Puya raimondii* communities have been increasingly affected by grazing and human influence. The natural vegetation is being disturbed and *Puya raimondii* has regularly been cut down and burned to prevent livestock becoming ensnared in the spines of the giant rosettes. Fire has been regularly observed on several mountain slopes. These fires were probably started on purpose as part of a festivity in June. Fortunately, due to advice and information given to the local communities by the first author, this practice is now gradually decreasing (personal observation), and conservation programs have been started. At the same time, interviews with the local communities suggest that the pastures are being grazed in a way that prevents overgrazing. Negative effects have been observed only in some grassland communities where livestock is abundant and species richness is relatively poor (communities of *Misbrookea strigosissima* and *Stipa ichu*, and *Plagiobothrys humilis* and *Stipa ichu*) and where tussock grasses are abundant and cover almost 70% of the ground. In addition to livestock, wild grazers including vicuñas (*Vicugna vicugna*), viscacha (*Lagidium peruanum*), taruca (*Hippocamelus antisensis*) and suri (lesser rhea, *Rhea pennata*) are known to occur in the region. It is also known that the villagers harvest the wood of *Escallonia myrtilloides* for fuel and for use in festivities, causing gradual decline of their stands. This highlights the vulnerability of the flora and vegetation of the Andes to human pressure, and requires further studies.

Appendix 1. Synoptic table of the plant communites. Presence values I (1–20), II (21–40), III (41–60), IV (61–80), V (81–100). 1. ***Plantagini sericeae-Plazietum daphnoidis***, 2. ***Phacelio secundae-Ribesetum brachybothryos***, 3. ***Neowerdermannio peruvianae-Festucetum weberbaueri***, 4. ***Hypochaerido mucidae-Valerianetum nivalis***, 5. ***Paronychio ubinensis-Hypochaeridetum mucidae***, 6. ***Hypochaerido mucidae-Paronychietum muschleri***, 7. Community of ***Asplenium triphyllum*** and ***Polystichium orbiculatum***, 8. ***Baccharido tricuneatae-Puyetum raimondii senecionetosum ferreyrae***, 9. B.-P. ***ageratinetosum sternbergianae***, 10. B.-P. ***lupinetosum cuzcensis***, 11. ***B.-P. calamagrostietosum heterophyllae***, 12. ***Sisyrinchio rigidifolii-Parastrephietum quadrangularis***, 13. Community of ***Misbrookea strigosissima*** and ***Stipa ichu***, 14. Community of ***Plagiobothrys humilis*** and ***Stipa ichu***, 15. ***Baccharido caespitosae-Azorelletum diapensioidis***, 16. ***Parastrephio lucidae-Festucetum orthophyllae*** (Galán de Mera el al. 2009), 17. ***Baccharido tricuneatae-Puyetum raimondii*** (Galán de Mera et al. 2009), 18. ***Parastrephio quadrangularis-Festucetum dolichophyllae*** (Galán de Mera et al. 2011), 19. ***P.-F. agrostietosum gelidae*** (Galán de Mera et al. 2011b), 20. ***P.-F. festucetosum orthophyllae*** (Galán de Mera et al. 2011b), 21. ***Parastrephio lucidae-Festucetum orthophyllae deyeuxietosum cabrerae*** (Galán de Mera et al. 2011b), 22. ***Wernerio aretioidis-Parastrephietum lucidae*** (***Azorello compactae-Festucion orthophyllae***) (Luebert & Gajardo 2005), 23. ***Parastrephio lucidae-Festucetum orthophyllae*** (Galán de Mera el al. 2003), 24. ***Parastrephio lucidae-Festucetum orthophyllae azorellietosum compactae*** (Galán de Mera el al. 2003), 25. ***Senecio nutantis-Parastrephietum quadrangularis*** (Galán de Mera et al. 2011b), 26. ***Parastrephietum lepidophyllo-quadrangularis*** (Luebert & Gajardo 2005), 27. ***Mutisio lanigerae-Polylepidetum tarapacanae*** (***Polylepidion tomentello-tarapacanae***) (Luebert & Gajardo 2005), 28. ***Muhlenbergio fastigatae-Parastrephietum lepidophyllae*** (Navarro 1993), 29. ***Acantholippio salsoloidis-Lampayetum castellani*** (Navarro 1993), 30. ***Diplostephio tacorensis-Parastrephietum lepidophyllae*** (Galán de Mera et al. 2003), 31. ***Chuquirago rotundifoliae-Polylepidetum rugulosae*** (***Polylepidion tomentello-tarapacanae***) (Luebert & Gajardo 2005).

	THIS STUDY															REFERENCES															
#order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
# rel	6	10	6	9	15	8	4	15	19	10	7	20	9	9	10	3	7	8	5	6	6	9	9	11	5	8	4	9	8	30	4
# spp	32	27	41	22	46	19	15	96	96	57	52	88	28	15	56	15	37	45	26	33	18	24	32	38	22	39	19	57	38	82	35
Characteristics of Argyrochosmetea niveae & Salpichroetalia glandulosae																															
Luzula racemosa	100	60	100	.	73	100	4	33	53	40	.	15	.	.	30	.	.	.	.	.	.	.	11	.	.	.	.	.	.	.	.
Salpichroa glandulosa	33	100	100	44	.	.	2	40	58	.	.	15	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa schultzii	.	50	33	.	60	38	.	.	21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ribes brachybothrys	.	70	.	100	.	.	2	7	48	.	.	.	.	.	.	.	57	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Peperomia scutellaefolia	67	.	100	100	.	88	.	27	21	.	.	.	44	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bomarea dulcis	.	50	.	67	20	.	3	40	11	.	.	.	.	.	30	.	.	.	.	.	.	.	.	9	.	.	.	.	.	.	.
Senecio sublutescens	.	.	100	.	.	88	4	33	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes pilosa	.	.	.	.	.	100	.	40	74	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pellaea ternifolia	83	.	.	.	.	.	.	.	26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	3	.
I. Argyrochosmo niveae-Neowerdermannion peruvianae																															
Argyrochosma nivea	83	40	67	.	.	.	.	7	26	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	1
Neowerdermannia peruviana	33	20	100	.	.	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phacelia pinnatifida	.	50	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	.	.	.
1. Plantagini sericeae-Plazietum daphnoidis																															
Plazia daphnoides	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Plantago sericea	83	.	.	.	7	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes scariosa	67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes myriophylla	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polypodium pycnocarpum	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aa mathewsii	33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2. Phacelio secundae-Ribesetum brachybothryos																															
Phacelia secunda	.	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3. Neowerdermannio peruvianae-Festucetum weberbaueri																															
Festuca weberbaueri	.	.	67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asplenium peruvianum	.	.	67	.	13	.	.	7	16	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Echeveria peruviana	17	.	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elaphoglossum minutum	.	.	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Campyloneurum amphostenon	.	.	33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
II. Hypochaerido mucidae-Loricarion graveolentis																															
Hypochaeris mucida	.	.	.	100	67	88	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa kunthiana	.	.	.	100	93	100	.	.	26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Loricaria graveolens	.	.	.	11	27	100	2	27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4. Hypochaerido mucidae-Valerianetum nivalis																															
Valeriana nivalis	.	.	.	100	.	.	.	.	37	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio sp. (#3729)	.	10	.	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium polium	.	.	.	67	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5. Paronychio ubinensis-Hypochaeridetum mucidae																															
Paronychia ubinensis	.	.	.	.	67	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia andina	.	.	.	.	47	.	.	13	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nototriche foetida	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	67	.	.	.	25	.	.	.	.	.
Chaetanthera peruviana	.	.	.	.	27	.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.	.	.	.
6. Hypochaerido mucidae-Paronychietum muschleri																															
Paronychia muschleri	.	.	.	.	.	88	.	.	.	.	.	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Draba sp.	.	.	.	.	.	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

#order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Calamagrostietea vicunarum																															
Calamagrostis vicunarum	.	.	.	.	47	88	.	40	11	100	.	10	78	.	70	.	14	50	20	67	100	.	78	45	.	50	.	.	.	10	.
Parastrephietalia quadrangularis																															
Parastrephia quadrangularis	.	.	.	.	33	.	.	100	58	90	71	100	100	89	100	1	14	88	40	100	.	33	56	64	80	100	4	67	100	50	1
Tetraglochin cristatum	.	.	.	.	20	.	.	7	37	60	29	40	100	89	90	.	86	63	60	83	.	44	78	27	80	13	.	33	100	40	.
Cumulopuntia boliviana subsp. *ignescens*	.	.	.	.	.	.	.	67	53	70	57	75	.	45	30	.	29	25	20	.	.	11	11	82	100	.	2	.	.	.	.
Baccharis tricuneata	.	.	.	.	20	.	.	93	90	90	57	75	78	.	50	3	100	75	100	33	.	.	22	18	.	75	.	.	.	.	.
Festuca dolichophylla	.	.	.	.	40	.	.	93	79	80	.	50	.	.	70	.	.	100	100	100	.	.	.	.	.	.	.	.	.	.	.
Plantago sericea var. *lanuginosa*	.	.	.	.	40	.	.	7	58	60	14	20	78	.	100	.	.	13	.	67	.	.	.	.	.	.	.	11	.	.	.
Gomphrena meyeniana	.	.	33	.	.	.	.	47	16	.	.	20	89	.	80	.	.	.	20	.	.	.	.	.	.	.	.	11	.	3	.
Chersodoma jodopappa	.	40	83	.	40	.	.	87	79	10	43	65	.	.	.	3	43	13	20	33	.	.	.	9	20	.	.	.	.	37	2
Ephedra rupestris	.	20	.	.	.	.	.	.	11	.	14	50	78	11	40	.	.	.	.	67	.	.	22	45	.	25	1	11	.	37	.
+Azorello compactae-Festucion orthophyllae																															
Tarasa nototrichoides	.	.	.	.	.	.	.	40	63	60	86	100	100	89	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Conyza deserticola	.	.	.	.	.	.	.	20	42	80	57	85	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lobivia maximiliana	.	.	.	11	33	.	.	47	68	30	.	25	.	.	10	.	43	13	.	.	.	.	.	.	.	.	.	.	.	.	.
Geranium sessiliflorum	.	.	.	.	.	.	.	47	37	.	.	20	100	78	.	.	14	13	20	.	.	.	.	.	.	.	.	.	.	.	.
Belloa longifolia	.	.	.	.	.	.	.	27	16	.	.	20	67	.	.	.	.	50	20	.	.	.	.	.	.	13	.	.	.	.	.
Oxalis calachaccensis	.	.	.	.	.	.	.	7	21	.	29	15	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lepechinia meyenii	.	.	.	.	.	.	.	20	37	.	100	40	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.	.	.	.
Philibertia lysimachioides	.	.	17	.	.	.	.	.	21	.	29	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Wahlenbergia peruviana	.	.	.	.	20	.	.	7	.	40	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clinopodium bolivianum	.	.	33	.	.	.	.	53	42	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Azorella compacta	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	66	11	.	100	20	89	3	.	.	.	.
8. Baccharido tricuneatae-Puyetum raimondii																															
Puya raimondii	.	.	.	.	.	.	.	87	74	100	100	.	.	.	.	.	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mutisia orbignyana	.	.	.	.	.	.	.	73	37	20	14	20	.	.	.	.	43	.	.	.	.	.	.	.	.	.	.	.	.	7	.
Lupinus paruroensis	.	.	.	.	.	.	.	33	26	80	100	20	.	.	.	.	.	.	.	67	.	.	11	18	.	13	.	.	.	13	.
Alstroemeria pygmaea	.	.	.	.	.	.	.	53	.	40	86	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Baccharis genistelloides	.	.	.	.	.	.	.	20	11	30	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	.	.	.	.
Lophopappus tarapacanus	33	.	.	.	.	.	.	20	26	.	14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17	2
Euphorbia huanchahana	.	.	.	.	.	.	.	40	.	40	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8.1 senecionetosum ferreyrae																															
Ageratina azangaroensis	.	.	.	.	.	.	.	87	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio ferreyrae	.	.	.	.	.	.	.	67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stevia macbridei	.	.	.	.	.	.	.	53	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bomarea involucrosa	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8.2 ageratinetosum sternbergianae																															
Ageratina sternbergiana	.	.	.	.	.	.	.	.	63	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Weberbauera peruviana	.	.	.	.	.	.	.	.	74	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stevia mandonii	.	30	.	.	.	.	.	.	74	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca orthophylla	.	.	.	.	.	.	.	.	11	.	.	.	.	.	.	3	43	.	.	50	83	100	100	100	40	100	3	89	63	3	.
8.4 lupinoetosum cuzcensis																															
Lupinus cuzcensis	.	.	.	.	.	.	.	.	.	90	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxalis nubigena	.	.	.	.	.	.	.	.	.	90	.	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio nutans	.	.	.	.	.	.	.	.	.	80	.	.	.	.	.	2	.	.	.	67	33	11	11	27	20	100	1	.	.	.	.
Olsynium junceum	.	.	.	.	.	.	.	.	.	70	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis violacea	.	.	.	.	.	.	.	.	.	70	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium dombeyanum	.	.	.	.	.	.	.	7	.	70	.	.	.	.	10	.	.	.	.	17	.	.	.	.	.	.	.	.	.	17	.
Lupinus sp. 1 (#3713)	.	.	.	.	.	.	.	.	.	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8.3 calamagrostietosum heterophyllae																															
Viola micranthella	.	.	.	.	.	.	.	7	.	.	100	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa gymnantha	.	.	.	.	.	.	.	.	.	10	86	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis heterophylla	.	.	.	.	.	.	.	7	.	.	71	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stipa obtusa	.	.	.	.	.	.	.	.	.	.	43	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.
9. Sisyrinchio rigidifoli-Parastrephietum quadrangulare																															
Sisyrinchium rigidifolium	.	.	50	.	.	.	.	.	16	.	14	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene genovevae	.	.	.	.	.	.	.	.	.	.	.	75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bartsia melampyroides	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oenothera nana	.	.	.	.	.	.	.	.	.	.	.	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalus arequipensis	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	13	.	.	.	.	.	.	.	13	.	.	.	10	.
10. Community of *Misbrookea strigosissima* and *Stipa ichu*																															
Misbrookea strigosissima	.	.	.	.	.	.	.	.	.	.	.	.	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stenomesson sp. (#3871)	.	.	.	.	.	.	.	.	.	.	29	.	89	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa sp.1 (#3824)	.	.	.	.	.	.	.	.	.	.	.	.	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio rhizocephalus	.	.	.	.	.	.	.	.	.	.	.	.	67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perezia coerulescens	.	.	.	.	.	.	.	.	.	.	.	20	56	.	.	.	.	.	.	.	.	.	.	+	.	13	.	.	.	3	.
11. Community of *Plagiobothrys humilis* and *Stipa ichu*																															
Plagiobothrys humilis	.	.	.	.	.	.	.	.	.	.	.	.	.	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Urtica echinata	.	.	.	.	.	.	.	.	.	.	.	10	.	56	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria sp. (#2272)	.	.	.	.	.	.	.	.	.	.	.	.	.	56	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
+Calamagrostion minimae																															
Calandrinia acaulis	.	.	.	.	7	38	.	.	47	.	.	.	.	22	80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus ananeanus	.	.	.	.	73	.	.	.	.	40	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12. Baccharido caespitosae-Azorelletum diapensioidis																															
Azorella diapensioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	70	.	.	.	.	50	50	.	.	.	.	13	.	.	.	.	.
Baccharis caespitosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.	.	.	.	17	.	.	.	18	.	13	.	.	.	.	.
Calamagrostis curvula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	1	29	13	.	100	33	11	22	64	.	.	.	.	.	.	.
Senecio humillimus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	33	22	.	.	.	.	22	.	.	.
Sisyrinchium brevipes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pycnophyllum molle	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	50	100	11	56	45	20	.	3	.	.	.	.
.																															
Crassuletea connatae																															
Muhlenbergia peruviana	67	.	.	.	80	.	.	33	68	90	100	100	100	.	80	.	43	13	.	83	.	.	.	.	.	.	.	44	.	3	.
Crassula connata	67	.	.	.	.	.	.	27	37	30	57	35	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tagetes multiflora	67	.	.	.	.	.	.	53	79	20	43	85	67	.	.	.	.	25	.	.	.	.	.	.	.	.	.	22	75	53	.
Mancoa hispida	.	.	.	.	.	.	.	.	21	.	14	25	.	33	20	.	.	.	.	.	.	.	.	.	.	.	.	11	.	.	.
Echinopsio-Proustietea																															
Vasquezia oppositifolia	33	.	100	.	.	.	.	7	16	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viguiera procumbens	.	.	67	.	.	.	.	.	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia setigera	.	.	.	.	.	.	.	27	11	.	29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium lacteum	.	.	.	.	27	.	.	27	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caiophora cirsiifolia	.	.	33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dunalia spinosa	.	.	33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

#order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Soncho-Bidentetea pilosi																															
Trifolium amabile	.	.	.	.	.	.	.	13	21	10	.	15	.	.	.	.	.	63	.	17	.	.	.	.	.	.	.	33	.	.	.
Polypodio-Tillandsietea																															
Tillandsia capillaris	67	40	.	.	.	.	.	.	21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
COMPANIONS																															
Stipa ichu	67	60	100	.	.	.	.	80	74	100	100	100	100	100	100	.	86	75	20	100	50	.	11	45	.	50	.	44	50	30	.
Belloa piptolepis	17	40	33	100	100	100	.	67	68	60	14	65	78	67	50	1	14	.	.	.	.	.	22	36	.	13	.	.	.	10	.
Galium corymbosum	67	20	67	.	53	.	.	100	68	100	100	95	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.	.	.	.
Nassella inconspicua	.	20	.	100	67	.	.	20	95	100	86	70	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypochaeris meyeniana	.	.	67	.	80	.	.	7	74	100	71	45	100	11	70	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.
Cardionema ramosissimum	67	.	50	.	27	.	.	60	63	10	14	20	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	67	25	.	1
Oxalis megalorrhiza	67	30	67	.	13	.	.	47	53	.	14	65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia fasciculata	17	.	67	.	.	.	.	.	32	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bartsia peruviana	.	.	50	.	.	.	.	47	21	20	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium subspicatum	.	.	.	100	.	75	3	47	37	.	.	30	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium streptochaetum	83	.	.	.	60	75	.	87	100	70	86	30	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bromus catharticus	.	40	100	.	27	38	4	53	63	40	.	40	.	.	.	.	.	38	20	.	.	.	.	.	.	.	.	.	.	.	.
Woodsia montevidensis	.	.	67	100	.	.	3	80	16	40	.	30	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes pruinata	100	.	100	78	67	.	.	93	95	40	57	60	.	.	.	.	14	.	.	.	.	.	.	.	.	.	.	.	.	7	.
Cystopteris fragilis	.	20	.	.	.	.	2	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calceolaria lobata	.	.	50	.	.	.	3	13	37	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bartsia crenoloba	.	.	.	.	60	.	.	47	79	50	57	40	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gamochaeta purpurea	.	.	.	.	13	.	.	40	26	.	71	15	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solanum bukasovii	.	.	.	67	.	.	.	27	11	.	14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bowlesia lobata	.	.	83	100	.	.	.	20	63	20	71	90	56	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana interrupta	50	30	.	78	.	.	.	73	73	.	43	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Achyrocline alata	.	.	33	.	.	.	.	7	26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana radicata	.	.	.	.	13	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio evacoides	.	.	.	.	.	.	.	.	.	.	.	15	.	.	40	.	.	.	20	.	.	.	.	.	.	.	.	.	.	7	.
Hypochaeris chillensis	.	.	.	.	.	.	.	47	47	20	86	85	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.	.	.	.
Quinchamalium procumbens	.	.	.	.	.	.	.	27	.	.	.	10	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.	.	17	.
Brayopsis calycina	.	.	.	.	13	.	.	.	.	.	.	.	.	.	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Achyrocline ramosissima	.	.	100	.	13	.	.	60	58	10	100	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Descurainia depressa	.	30	.	.	.	.	.	.	11	.	.	20	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aristeguietia ballii	.	.	100	.	7	.	.	27	32	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia andina	.	.	83	100	100	.	.	7	11	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coreopsis fasciculata	33	.	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	75	60	.	.	.	.	.	.	.	.	.	.	.	.
Brayopsis monimocalyx	.	.	.	.	20	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ourisia muscosa	.	.	.	.	27	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gilia laciniata	.	.	.	.	.	.	.	.	.	60	86	70	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.	.	.	.
Bidens andicola	.	.	.	.	.	.	.	53	63	10	.	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Microsteris gracilis	.	.	.	.	.	.	.	20	.	100	86	.	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes arequipensis	.	.	.	.	.	.	.	.	37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria digyna	.	.	.	.	.	.	.	.	.	.	.	25	.	.	80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perezia pungens	.	.	.	.	.	.	.	40	.	.	.	60	.	.	10	.	.	25	20	.	.	.	.	.	.	.	.	.	.	.	.
Senecio candolleii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Laennecia artemisioides	.	.	.	.	.	.	.	7	.	.	86	.	100	.	20	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Calceolaria inamoena	.	.	.	.	.	.	.	47	16	10	14	.	.	.	.	.	14	.	.	.	.	.	.	.	.	.	.	.	.	7	.
Galinsoga mandonii	.	.	.	.	.	.	.	27	42	.	43	45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium americanum	.	.	.	.	.	.	.	27	32	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyperus seslerioides	.	.	.	.	47	.	.	53	74	.	100	40	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	11	.	.	.
Facelis plumosa	.	.	.	.	.	.	.	20	79	30	29	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ephedra americana	.	.	.	.	.	.	.	7	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	38	.	.
Vicia andicola	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium aparine	.	.	.	.	.	.	.	7	21	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Other species: In 1 *Oreocereus hendriksenianus* 17, *Puya ferruginea* 17, *Triniochloa stipoides* 17; in 2 *Saxifraga magellanica* 10; in 3 *Descurainia myriophylla* 17, *Paronychia weberbaueri* 20, *Senecio klattii* 20; in 4 *Belloa* sp.2, *Perezia ciliosa* 22; in 5 *Aristida adscencionis* 13, *Cerastium* sp. (# 3728) 13; in 8 *Aphanes andicola* 20, *Ephedra americana* 7, *Eragrostis nigricans* 7, *Escallonia myrtilloides* 13, *Philibertia solanoides* 13; in 8 *Solanum chamaesarachidium* 13, *Solanum fragile* 7, *Triniochloa stipoides* 20; in 9 *Adesmia spinosissima* 16, *Bougueria nubicola* 16, *Castilleja laciniata* 11, *Ephedra americana* 11, *Eragrostis nigricans* 11, *Escallonia myrtilloides* 11, *Geranium* core-core 11, *Solanum* fragile 11; in 10 *Solanum fragile* 10; in 12 *Adesmia miraflorensis* 15, *Adesmia spinosissima* 15, *Astragalus micranthellus* 20, *Chondrosum simplex* 15, *Eragrostis nigricans* 10, *Geranium core -core* 15, *Plantago* sp. (Image 0397, 15/04/2012) 20, *Perezia sublyrata* 20, *Lobivia* sp. 20, *Hedeoma mandoniana* 15, *Ophioglossum crotalophoroides* 15, *Valeriana coarctata* 5; in 12 *Vicia andicola* 20, *Junellia minima* 20, Perezia *pinnatifida* 10, Nototriche *anthemidifolia* 20, *N . pedicularifolia* 10, *Oreomyrrhis andicola* 10, *Pycnophyllum glomeratum* 10; in 15 *Oxalis* eriolepis 20, *Sisyrinchium jamesonii* 20, *Aa rosei* 10.

SPECIES FROM OTHER STUDIES																															
Parastrephia lucida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	100	100	67	9	.	.	3	.	.	.	.
Senecio spinosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	40	33	33	11	56	9	20	13	.	.	.	7	.
Poa candamoana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14	50	100	83	17	.	11	.	.	13	.	.	.	3	.
Nassella brachyphylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	43	.	.	.	.	.	11	9	.	.	.	.	.	.	.
Chuquiraga rotundifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	29	.	.	.	.	.	.	.	.	.	.	.	.	20	4
Polylepis rugulosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	25	.	.	.	.	3
Diplostephium tovarii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	57	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nassella pubiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	86	25	.	17	.	.	.	.	.	.	.	.	.	13	1
Astragalus garbancillo	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	22	63	.	.
Parastrephia lepidophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	100	.	.	.	.	.	1
Baccharis buxifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	57	.	.	.	.	.	.	.	.	13	.	.	.	.	.
Diplostephium tacorense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.	.	.	.	.	.	.	.	.	.	.	53	.
Calceolaria xerophila	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mutisia hastata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio phylloleptus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Deyeuxia heterophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13	20	67	.	.	.	.	.	25	.	22	.	.	.
Plantago linearis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	20	.	.	.	.	.	.	.	.	.	.	7	.
Opuntia soehrensii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	13	.	.	.	.	.	.	.	.	.	.	.	40	2
Nassella mucronata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	60	83	.	.	.	.	.	.	.	11	.	.	.
Bartsia elongata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	40	.	.	.	.	.	.	.	.	.	.	.	.
Vulpia megalura	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	.	.	.	.	.	.	.	.	.	.	.	3	.
Bidens pilosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.	.	.	.	.	.	.	.
Nassella depauperata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	56	.	.	.
Hordeum muticum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	22	.	.	.
Paranephelius ovatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	75	60	17	.	.	.	.	.	.	.	.	.	.	.
Bartsia camporum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.	50	.	.	.	.	.	.	.	.	.	.	.
Agrostis gelida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus saxatilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	38	.	.	.	.	.
Deyeuxia cabrerae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17	100	.	.	.	.	.	.	.	.	.	.
Nototriche argentea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	.	.	.	.	.
Astragalus sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	20	.	.	.	.	.	.
Adesmia patancana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	.	.	.	.	.
Perezia ciliosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	.	.	.	.	.
Baccharis incarum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	11	100	60	.	2	56	50	50	4
Nototriche obcuneata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	.	.	.	.
Dissanthelium peruvianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	.	.	3	.
Arenaria serpens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	.	.	.	.
Nassella nardoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	20	.	.	11	88	.	.
Nassella asplundii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	.	.	53	.
Deyeuxia intermedia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	.	.	23	.

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Festuca rigescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	.	.	.	.	13	.	.	.	3	.
Calamagrostis breviaristata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	78	.	.	60	13	1	33	13	.	.
Werneria aretioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100	33	.	.	.	2	.	.	.	.
Ephedra breana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	3
Adesmia melanthes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	1	.	.	.	.
Tarasa tenella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	25	.	.
Schkuhria pusilla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	67	75	.	.
Gnaphalium cheiranthifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	44	13	.	.
Stipa holwayi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	13	.	.
Heterosperma nana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	13	.	.
Muhlenbergia fastigata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	78	.	.	.
Hoffmannseggia minor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	44	.	.	.
Euphorbia ovalifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	.	.	.
Distichlis humilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	.	.	.
Bromus uniloides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Oxalis bisfracta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Plagiobothrys congestus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Aristida asplundii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Ombrophytum subterraneum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Geranium sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Solanum sinuatirecurvum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.
Nassella linearifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	67	25	.	.
Gomphrena umbellata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	25	.	.
Lampaya castellani	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100	.	.
Acantholippia salsoloides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	88	.	.
Verbena seriphioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	88	.	.
Opuntia glomerata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63	.	.
Fabiana densa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63	.	.
Stipa curviseta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63	.	.
Senecio potosianus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	.	.
Gutierrezia gilliesii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.
Fabiana stephanii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	47	.
Opuntia corotilla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	.
Baccharis boliviensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	13	23	4
Corryocactus brevistylus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	.
Franseria fruticosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	.
Opuntia sphaerica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.
Tarasa operculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.

Other species: In 16 *Avena* sp. 1; in 17 *Xenophyllum poposum* 17, *Opuntia floccosa* 14, *Bomarea uniflora* 14, *Solanum* sp. 14, *Buddleia coriacea* 14, *Plantago sericea* subsp. *sericans* 14; in 18 *Solanum acaule* 13, *Lepidium chichicara* 13, *Erodium cicutarium* 13, *Schkuhria multiflora* 13; in 19 *Lupinus microphyllus* 20; in 20 *Senecio graveolens* 17, *Dissanthelium macusaniense* 17, *Lupinus microphyllus* 17, *Mutisia arequipensis* 17, *Erigeron incanus* 17, *Hypochaeris eriolaena* 17; in 21 *Pycnophyllum weberbaueri* 17, *Poa aequigluma* 17, *Deyeuxia brevifolia* 17, *Pycnophyllum* sp. 17; in 22 *Werneria* sp. 11, *Senecio graveolens* 11, *Deyeuxia nardifolia* 11, *Nototriche* sp. 11, *Gamochaeta* sp. 11, *Werneria glaberrima* 11; in 23 *Echinopsis huotii* 11, *Bartsia diffusa* 11, *Plantago monticola* 11, *Dissanthelium calycinum* 11, *Werneria pectinata* 11, *Astragalus pusillus* 11, *Werneria* sp. 11; in 24 *Xenophyllum poposum* 18, *Bartsia diffusa* 11, *Dielsiochloa floribunda* 9, *Werneria apiculata* 9, *Dissanthelium calycinum* 9, *Werneria pectinata* 9, *Anatherostipa rigidiseta* 9, *Aciachne pulvinata* 9, *Caiophora superba* 9, *Oxalis pachyrrhiza* 9, *Hypochaeris taraxacoides* 9; in 25 *Paronychia microphylla* 20, *Deyeuxia* sp. 20, *Stipa leptostachya* 20; in 26 *Astragalus uniflorus* 13, *Senecio rudbeckiifolius* 13, *Stipa annua* 13, *Perezia multiflora* 13, *Anthochloa lepidula* 13, *Senecio adenophylloides* 13, *Tephrocactus lagopus* 13, *Senecio graveolens* 13, *Erigeron incanus* 13; in 27 *Polylepis tarapacana* 4, *Chersodoma candida* 2, *Senecio zoellneri* 1, *Stipa venusta* 1, *Nototriche* sp. 1, *Adesmia melanthes* 1; in 28 *Hypochaeris elata* 11, *Conyza deserticola* 11, *Neowerdermannia vorwerkii* 11, *Tarasa tarapacana* 11, *Plantago orbignyana* 11, *Festuca humilior* 11, *Verbena* sp. 11, *Gnaphalium badium* 11, *Calycera pulvinata* 11, *Opuntia boliviana* 11; in 29 *Taraxacum officinale* 13, *Capsella bursa-pastoris* 13, *Opuntia steiniana* 13, *Senecio vulgaris* 13, *Lupinus* sp. 13, *Perezia* sp. 13, *Opuntia boliviana* 13; in 30 *Junellia juniperina* 20, *Polylepis besserii* 20, *Spergularia congestifolia* 20, *Grindelia boliviana* 17, *Hypochaeris taraxacoides* 17, *Oreocereus tacnaensis* 17, *Plantago monticola* 17, Brassicaceae 17, *Balbisia meyeniana* 13, *Junellia arequipense* 13, *Bromus lanatus* 13, *Eragrostis weberbaueri* 13, *Senecio adenophyllus* 10, *Echinopsis huotii* 10, *Opuntia subulata* 7, *Bartsia diffusa* 7, *Oreocereus hempelianus* 7, *Anatherostipa rigidiseta* 7, *Oritrophium peruvianum* 7, *Paronychia microphylla* 3, *Chersodoma arequipensis* 3, *Stipa nardoides* 3, *Proustia foliosa* 3, *Glandularia laciniata* 3, *Polyachyrus sphaerocephalus* 3, *Ophryosporus heptanthus* 3, *Baccharis latifolia* 3, *Stipa* sp. 3, *Dielsiochloa floribunda* 3, *Dissanthelium breve* 3, *Senecio richii* 3, *Solanum peruvianum* 3, *Viguiera procumbens* 3, *Euphorbia* sp. 3, *Senecio clivicolus* 3, *Bidens triplinervia* 3, *Mutisia acuminata* 3, *Ophryosporus peruvianus* 3; in 31 *Calceolaria pulchella* 4, *Fabiana* ramulosa 4, *Opuntia echinacea* 4, *Quinchamalium* chilense 4, *Opuntia berteroi* 2, *Neoporteria* sp. 2, *Junellia seriphioides* 2, *Lupinus oreophilus* 1, *Diplostephium cinereum* 1, *Mutisia hamata* 1, *Chenopodium petiolare* 1, *Mutisia lanigera* 1, *Stipa* sp. 1, *Senecio olivaceobracteatus* 1, *Descurainia* sp. 1, *Sisyrinchium* sp. 1, *Plantago monticola* 1.

Appendix 2. Typus relevés of all the new associations and subassociations.

In 1: Rel. number 5, altitude 3820 m, slope 60°, aspect SW, rocks 90%, stones 1%, vegetation cover 30 %, number of species 22; ***Plantago sericea*** 3, ***Plazia daphnoides*** 3, ***Stipa ichu*** 3, ***Coreopsis fasciculata*** 2, ***Oreocereus hendriksenianus*** 2, ***Triniochloa stipoides*** 2, ***Aa mathewsii*** 1, ***Argyrochosma nivea*** 1, ***Cardionema ramosissimum*** 1, ***Cheilanthes myriophylla*** 1, ***Cheilanthes pruinata*** 1, ***Cheilanthes scariosa*** 1, ***Galium corymbosum*** 1, ***Hieracium streptochaetum*** 1, ***Luzula*** racemosa 1, Muhlenbergia peruviana 1, Oxalis ***megalorrhiza*** 1, ***Pellaea ternifolia*** 1, ***Peperomia*** scutellaefolia 1, Polypodium pycnocarpum 1, ***Tillandsia capillaris*** 1, ***Vasquezia oppositifolia*** 1.

In 2: Rel. number 9, altitude 4500 m, slope 60°, aspect SE, rocks 15%, stones 80%, vegetation cover 25%, number of species 14; ***Ribes brachybothrys*** 5, ***Salpichroa glandulosa*** 4, ***Tillandsia capillaris*** 4, ***Chersodoma jodopappa*** 2, ***Phacelia pinnatifida*** 2, ***Argyrochosma nivea*** 1, ***Belloa piptolepis*** 1, ***Bromus catharticus*** 1, ***Cystopteris fragilis*** 1, ***Galium corymbosum*** 1, ***Neowerdermannia peruviana*** 1, ***Oxalis megalorrhiza*** 1, ***Phacelia secunda*** 1, ***Valeriana interrupta*** 1.

In 3: Rel. number 19, altitude 3960 m, Slope 70°, aspect SE, rocks 85%, stones 10%, vegetation cover 45%, number of species 31; ***Achyrocline ramosissima*** 3, ***Aristeguietia ballii*** 3, ***Festuca weberbaueri*** 3, ***Neowerdermannia peruviana*** 3, ***Salpichroa glandulosa*** 3, ***Bromus catharticus*** 2, ***Chersodoma jodopappa*** 2, ***Clinopodium bolivianum*** 2, ***Senecio sublutescens*** 2, ***Stipa ichu*** 2, ***Viguiera procumbens*** 2, ***Achyrocline alata*** 1, ***Argyrochosma nívea*** 1, ***Asplenium peruvianum*** 1, ***Belloa piptolepis*** 1, ***Bowlesia lobata*** 1, ***Campyloneurum amphostenon*** 1, ***Cardionema ramosissimum*** 1, ***Cheilanthes pruinata*** 1, ***Coreopsis fasciculata*** 1, ***Echeveria peruviana*** 1, ***Hypochaeris meyeniana*** 1, ***Luzula racemosa*** 1, ***Oxalis megalorrhiza*** 1, ***Paronychia andina*** 1, ***Peperomia scutellaefolia*** 1, ***Phacelia pinnatifida*** 1, ***Sisyrinchium rigidifolium*** 1, ***Spergularia fasciculata*** 1, ***Vasquezia oppositifolia*** 1, ***Woodsia montevidensis*** 1.

In 4: Rel. number 24, altitude 4090 m, slope 45°, aspect S, rocks 85%, stones 5%, vegetation cover 30%, number of species 15; ***Ribes brachybothrys*** 5, ***Nassella inconspicua*** 3, ***Valeriana nivalis*** 3, ***Cerastium subspicatum*** 2, ***Gnaphalium polium*** 2, ***Hypochaeris mucida*** 2, ***Paronychia andina*** 2, ***Senecio*** sp. (# 3729) 2, ***Valeriana interrupta*** 2, ***Belloa*** kunthiana 1, ***Belloa piptolepis*** 1, ***Bowlesia lobata*** 1, ***Cheilanthes pruinata*** 1, ***Peperomia scutellaefolia*** 1, ***Woodsia montevidensis*** 1.

In 5: Rel. number 34, altitude 4100 m, slope 5°, aspect W, rocks 85%, stones 5%, vegetation cover 25%, number of species 16. ***Hypochaeris meyeniana*** 3, ***Loricaria graveolens*** 3, ***Paronychia andina*** 3, ***Belloa piptolepis*** 2, ***Bartsia crenoloba*** 1, ***Belloa kunthiana*** 1, ***Bromus catharticus*** 1, ***Calamagrostis vicunarum*** 1, ***Cardionema ramosissimum*** 1, ***Hypochaeris mucida*** 1, ***Luzula racemosa*** 1, ***Muhlenbergia peruviana*** 1, ***Nassella inconspicua*** 1, ***Nototriche foetida*** 1, ***Paronychia ubinensis*** 1, ***Spergularia andina*** 1.

In 6: Rel. number 49, altitude 4360 m, slope 70°, aspect S, rocks 90%, stones 5%, vegetation cover 20%, number of species 15; ***Loricaria graveolens*** 4, ***Senecio sublutescens*** 2, ***Peperomia scutellaefolia*** 1, ***Luzula racemosa*** 1, ***Belloa schulzii*** 1, ***Cheilanthes pilosa*** 1, ***Hypochaeris mucida*** 1, ***Belloa kunthiana*** 1, ***Paronychia muschleri*** 1, ***Draba*** sp. (# 3720) 1, ***Calamagrostis vicunarum*** 1, ***Calandrinia acaulis*** 1, ***Belloa piptolepis*** 1, ***Hieracium streptochaetum*** 1, ***Brayopsis monimocalyx*** 1.

In 8: Rel. number 10, altitude 3860 m, slope 45°, aspect SW, rocks 25%, stones 45%, vegetation cover 75%, number of species 43; ***Puya raimondii*** 4, ***Stipa ichu*** 4, ***Baccharis tricuneata*** 3, ***Chersodoma jodopappa*** 3, ***Clinopodium bolivianum*** 3, ***Conyza deserticola*** 3, ***Mutisia orbignyana*** 3, ***Parastrephia quadrangularis*** 3, ***Salpichroa glandulosa*** 3, ***Achyrocline ramosissima*** 2, ***Bartsia peruviana*** 2, ***Bomarea*** *involucrosa* 2, *Bowlesia lobata* 2, *Cheilanthes pilosa* 2, *Cumulopuntia boliviana* subsp. *ignescens* 2, *Festuca dolichophylla* 2, *Hieracium streptochaetum* 2, *Hypochaeris chillensis* 2, *Lobivia* maximiliana 2, *Senecio ferreyrae* 2, *Senecio sublutescens* 2, *Solanum bukasovii* 2, *Stevia macbridei* 2, *Ageratina azangaroensis* 1, *Alstroemeria pygmaea* 1, *Aphanes andicola* 1, *Bartsia* crenoloba 1, *Belloa longifolia* 1, *Belloa piptolepis* 1, *Bromus catharticus* 1, *Cheilanthes pruinata* 1, *Euphorbia huanchahana* 1, *Galinsoga mandonii* 1, *Galium corymbosum* 1, *Gamochaeta purpurea* 1, *Geranium sessiliflorum* 1, *Muhlenbergia peruviana* 1, *Oxalis megalorrhiza* 1, *Solanum chamaesarachidium* 1, *Tagetes multiflora* 1, *Tarasa nototrichoides* 1, *Vasquezia oppositifolia* 1, *Woodsia montevidensis* 1.

In 9: Rel. number 28, altitude 4170 m, slope 45°, aspect E, rocks 20%, stones 55%, vegetation cover 70%, number of species 47; *Puya raimondii* 5, *Stipa ichu* 4, *Festuca dolichophylla* 3, *Achyrocline ramosissima* 2, *Ageratina sternbergiana* 2, *Baccharis* tricuneata 2, *Bartsia crenoloba* 2, *Belloa piptolepis* 2, *Clinopodium bolivianum* 2, *Conyza deserticola* 2, *Cumulopuntia boliviana* subsp. *ignescens* 2, *Ephedra rupestris* 2, *Geranium sessiliflorum* 2, *Hypochaeris chillensis* 2, *Hypochaeris meyeniana* 2, *Lepechinia meyenii* 2, *Nassella inconspicua* 2, *Parastrephia quadrangularis* 2, *Sisyrinchium rigidifolium* 2, *Stevia mandonii* 2, *Aristeguietia ballii* 1, *Bartsia peruviana* 1, Bidens *andicola* 1, *Bowlesia lobata* 1, *Bromus catharticus* 1, *Calceolaria inamoena* 1, *Cerastium subspicatum* 1, *Cheilanthes pilosa* 1, *Cheilanthes pruinata* 1, *Crassula connata* 1, *Cyperus seslerioides* 1, *Facelis plumosa* 1, *Galinsoga mandonii* 1, *Galium corymbosum* 1, *Gnaphalium americanum* 1, *Hieracium streptochaetum* 1, *Muhlenbergia peruviana* 1, *Mutisia orbignyana* 1, *Oxalis calachaccensis* 1, *Oxalis megalorrhiza* 1, *Salpichroa glandulosa* 1, *Spergularia fasciculata* 1, *Tagetes multiflora* 1, *Tarasa nototrichoides* 1, *Valeriana interrupta* 1, *Vasquezia oppositifolia* 1, *Weberbauera peruviana* 1.

In 10: Rel. number 35, altitude 4290 m, slope 30°, aspect NE, rocks 10%, stones 10%, vegetation cover 65%, number of species 36; *Festuca dolichophylla* 4, *Lupinus paruroensis* 4, *Mutisia orbignyana* 4, *Nassella inconspicua* 4, *Puya raimondii* 4, *Stipa ichu* 4, *Cumulopuntia boliviana* subsp. *ignescens* 3, *Parastrephia quadrangularis* 3, *Baccharis tricuneata* 2, *Calamagrostis vicunarum* 2, *Calceolaria lobata* 2, *Hypochaeris meyeniana* 2, *Lobivia maximiliana* 2, *Senecio nutans* 2, *Alstroemeria pygmaea* 1, *Bartsia crenoloba* 1, *Bowlesia lobata* 1, *Calamagrostis violacea* 1, *Cheilanthes pruinata* 1, *Conyza deserticola* 1, *Crassula connata* 1, *Euphorbia huanchahana* 1, *Facelis plumosa* 1, *Galium corymbosum* 1, *Gilia laciniata* 1, Gnaphalium *dombeyanum* 1, *Hieracium streptochaetum* 1, *Hypochaeris chillensis* 1, *Lupinus cuzcensis* 1, *Microsteris gracilis* 1, *Muhlenbergia peruviana* 1, *Olsynium junceum* 1, *Oxalis nubigena* 1, *Tagetes multiflora* 1, *Tarasa nototrichoides* 1, *Valeriana radicata* 1, Woodsia *montevidensis* 1.

In 11: Rel. number 49, altitude 4030 m, slope 40°, aspect NW, rocks 10%, stones 10%, vegetation cover 40%, number of species 28; *Lupinus paruroensis* 5, *Puya raimondii* 4, *Stipa ichu* 4, *Nassella inconspicua* 3, *Alstroemeria* pygmaea 2, *Baccharis tricuneata* 2, *Calamagrostis heterophylla* 2, *Cumulopuntia boliviana* subsp. *ignescens* 2, *Hieracium streptochaetum* 2, *Tetraglochin cristatum* 2, *Achyrocline ramosissima* 1, *Bowlesia lobata* 1, *Cheilanthes pruinata* 1, *Conyza deserticola* 1, *Cyperus seslerioides* 1, *Ephedra rupestris* 1, *Galium corymbosum* 1, *Gilia laciniata* 1, *Hypochaeris chillensis* 1, *Laennecia artemisioides* 1, *Lepechinia meyenii* 1, *Microsteris gracilis* 1, *Muhlenbergia peruviana* 1, *Parastrephia quadrangularis* 1, *Poa gymnantha* 1, *Stipa obtusa* 1, *Tarasa nototrichoides* 1, *Viola micranthella* 1.

In 12: Rel. number 3, altitude 4040 m, slope 25°, aspect ESE, rocks 20%, stones 15%, vegetation cover 70%, number of species 37; ***Parastrephia quadrangularis*** 5, ***Festuca dolichophylla*** 4, ***Stipa ichu*** 4, ***Nassella inconspicua*** 3, ***Baccharis tricuneata*** 2, ***Belloa longifolia*** 2, ***Caiophora chuquitensis*** 2, ***Cumulopuntia boliviana*** subsp. ***ignescens*** 2, ***Hieracium streptochaetum*** 2, ***Hypochaeris meyeniana*** 2, ***Lobivia*** sp. (Image 0468, 15/04/2012) 2, ***Philibertia lysimachioides*** 2, ***Sisyrinchium rigidifolium*** 2, ***Tetraglochin cristatum*** 2, ***Arenaria digyna*** 1, ***Astragalus*** arequipensis 1, ***Bartsia crenoloba*** 1, ***Conyza deserticola*** 1, ***Crassula connata*** 1, ***Cyperus seslerioides*** 1, ***Descurainia depressa*** 1, ***Facelis plumosa*** 1, ***Galium corymbosum*** 1, ***Gomphrena*** meyeniana 1, ***Hedeoma mandoniana*** 1, ***Hypochaeris chillensis*** 1, ***Muhlenbergia peruviana*** 1, ***Ophioglossum crotalophoroides*** 1, ***Oxalis nubigena*** 1, ***Perezia*** coerulescens 1, ***Plantago*** sp. (Image 0397, 15/04/2012) 1, ***Senecio evacoides*** 1, ***Tagetes multiflora*** 1, ***Tarasa nototrichoides*** 1, ***Vicia andicola*** 1, ***Viola micranthella*** 1, ***Woodsia montevidensis*** 1.

In 15: Rel. number 42, altitude 4380 m, slope 10°, aspect SW, rocks 20%, stones 10%, vegetation cover 55%, number of species 19; ***Azorella diapensioides*** 4, ***Pycnophyllum molle*** 4, ***Baccharis caespitosa*** 3, ***Parastrephia quadrangularis*** 3, ***Stipa ichu*** 3, ***Baccharis tricuneata*** 2, ***Calamagrostis curvula*** 2, ***Cumulopuntia boliviana*** subsp. ***ignescens*** 2, ***Festuca dolichophylla*** 2, ***Pycnophyllum glomeratum*** 2, ***Tetraglochin cristatum*** 2, ***Arenaria digyna*** 1, ***Brayopsis calycina*** 1, ***Calandrinia acaulis*** 1, ***Gomphrena meyeniana*** 1, ***Hypochaeris meyeniana*** 1, ***Paronychia andina*** 1, ***Plantago sericea*** var. ***lanuginosa*** 1, ***Valeriana nivalis*** 1.

Appendix 3. Chasmophyte communities of the *Argyrochosmo niveae-Neowerdermannion peruvianae* and *Hypochaerido mucidae-Loricarion graveolentis* of steep basalt cliffs (type relevés underlined).

# Relevé	1	2	3	4	5	6	PC	7	8	9	10	11	12	13	14	15	16	PC
Size (m²)	25	25	25	25	25	25		25	25	25	4	4	4	25	25	4	4	
Altitude (x10)	375	376	378	380	382	385		440	445	450	415	415	415	440	440	443	443	
Slope (°)	50	50	55	60	60	60		50	50	60	80	90	90	50	90	90	90	
Aspect	SW	SW	SW	SW	SW	SW		SE	SE	SE	E	E	E	SE	SE	E	E	
Rocks %	90	95	90	90	90	90		10	20	15	15	80	90	85	85	90	85	
Stones %	1	2	1	2	1	2		80	80	80	80	5	5	5	5	5	5	
Grazing (0-3)	0	0	0	0	0	0		0	0	0	0	0	0	1	0	0	0	
Manure (%)	0	0	0	0	0	0		0	0	0	0	0	0	1	0	0	0	
Vegetation Cover %	25	25	25	20	30	20		20	30	25	25	15	20	25	20	25	25	
# species	17	19	17	15	22	15		9	12	14	10	8	9	12	10	10	10	
Argyrochosmetea niveae																		
Salpichroetalia glandulosae																		
Salpichroa glandulosa	.	1	.	2	.	.	33	3	4	4	4	5	5	5	5	5	5	100
Peperomia scutellaefolia	1	1	.	.	1	1	67	.	.	.	.	.	.	.	.	.	.	.
Luzula racemosa	1	1	1	1	1	1	100	.	.	.	.	1	1	1	1	1	1	60
Pellaea ternifolia	1	1	1	1	1	.	83	.	.	.	.	.	.	.	.	.	.	.
Belloa schulzii	.	.	.	.	.	.	.	.	1	.	.	.	1	1	.	1	1	50
Senecio sublutescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ribes brachybothrys	.	.	.	.	.	.	.	.	5	5	5	.	4	4	.	4	5	70
Bomarea dulcis	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	1	1	50
Cheilanthes pilosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga magellanica	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	10
+Argyrochosmo niveae-Neowerdermannion peruvianae																		
Argyrochosma nivea	1	1	.	1	1	1	83	1	.	1	.	1	.	.	1	.	.	40
Neowerdermannia peruviana	.	2	2	.	.	.	33	.	.	1	.	.	.	.	.	.	1	20
Phacelia pinnatifida	.	.	.	.	.	.	.	2	.	2	.	.	1	1	.	1	.	50
Plantagini sericeae-Plazietum daphnoidis																		
Plazia daphnoides	4	4	4	4	3	4	100	.	.	.	.	.	.	.	.	.	.	.
Plantago sericea	2	.	3	2	3	2	83	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes scariosa	1	1	1	.	1	.	67	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes myriophylla	.	.	1	1	1	.	50	.	.	.	.	.	.	.	.	.	.	.
Polypodium pycnocarpum	1	1	.	.	1	.	50	.	.	.	.	.	.	.	.	.	.	.
Aa mathewsii	.	.	.	.	1	1	33	.	.	.	.	.	.	.	.	.	.	.
Phacelio secundae-Ribesetum brachybothryos																		
Phacelia secunda	.	.	.	.	.	.	.	2	2	1	1	2	1	1	2	2	1	100
Paronychia weberbaueri	.	.	.	.	.	.	.	.	.	.	.	.	2	3	.	.	.	20
Senecio klattii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	20
Neowerdermannio peruvianae-Festucetum weberbaueri																		
Festuca weberbaueri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asplenium peruvianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Echeveria peruviana	.	1	.	.	.	.	17	.	.	.	.	.	.	.	.	.	.	.
Elaphoglossum minutum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Campyloneurum amphostenon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
+Hypochaerido mucidae-Loricarion graveolentis																		
Hypochaeris mucida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa kunthiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Loricaria graveolens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypochaerido mucidae-Valerianetum nivalis																		
Valeriana nivalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio sp. (# 3729)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	10
Gnaphalium polium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perezia ciliosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychio ubinensis-Hypochaeridetum mucidae																		
Paronychia ubinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nototriche foetida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chaetanthera peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium sp. (# 3728)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypochaerido mucidae-Paronychietum muschleri																		
Paronychia muschleri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Draba sp. (# 3720)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Community of *Asplenium triphyllum* and *Polystichum orbiculatum*																		
Asplenium triphyllum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stellaria weddellii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polystichum orbiculatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Descurainia athrocarpa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

17	18	19	20	21	22	PC	23	24	25	26	27	28	29	30	31	PC	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	PC
25	25	25	25	25	25		25	25	25	25	25	25	25	25	25		25	25	25	25	36	36	25	25	25	25	25	25	36	36	36	
395	400	396	400	398	398		410	409	405	405	407	407	410	410	410		410	400	410	420	410	415	410	410	410	400	420	430	420	420	408	
70	80	70	80	70	70		40	45	45	40	50	50	45	50	50		5	10	5	10	35	35	10	5	10	10	10	10	40	40	35	
W	S	W	S	W	W		S	S	S	S	S	S	S	S	S		W	W	W	W	W	W	SW	SW	SW	W	W	W	SW	SW	W	
80	85	85	85	85	85		80	85	85	90	90	90	90	90	90		80	85	85	80	25	20	85	90	90	85	85	90	20	15	15	
10	10	10	5	5	5		5	5	5	2	5	5	5	5	2		5	2	5	5	10	10	5	5	5	2	5	2	10	10	10	
0	0	0	0	0	0		0	0	0	0	1	0	1	0	1		0	0	0	0	1	1	0	1	1	0	0	0	1	1	1	
0	0	0	0	0	0		0	0	0	0	0	0	1	0	1		0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	
45	40	45	40	50	45		35	30	25	25	25	20	25	25	25		20	30	25	25	50	55	30	30	30	30	20	20	55	50	60	
30	26	31	24	27	26		19	15	18	14	15	18	14	15	17		13	20	16	16	13	20	24	18	21	20	14	15	23	22	14	
2	4	3	4	3	2	100	1	.	1	.	.	1	.	.	1	44	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	1	1	1	1	1	100	1	1	1	1	1	1	1	1	1	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	1	1	1	1	1	100	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	1	1	.	2	1	1	.	2	1	.	73
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	1	.	1	.	.	33	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	.	1	1	1	1	1	1	.	60
3	2	2	3	3	3	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	5	5	3	5	3	3	5	3	5	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	1	.	1	1	.	1	1	.	1	67	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	20
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47	48	49	50	51	52	53	54	PC	55	56	57	58	PC
25	25	25	25	25	25	25	25		1	1	1	1	
430	440	436	438	420	405	410	415		450	450	450	450	
60	80	70	80	70	60	60	80		90	70	80	90	
S	S	S	S	S	S	S	S		W	W	W	W	
90	90	90	90	90	90	95	90		90	95	95	95	
5	5	5	2	1	1	2	1		1	1	1	1	
0	0	0	0	0	0	0	0		0	0	0	0	
0	0	0	0	0	0	0	0		0	0	0	0	
25	15	20	15	15	15	15	15		20	15	15	15	
17	14	15	14	11	12	10	10		13	9	12	10	
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# Relevé	1	2	3	4	5	6	PC	7	8	9	10	11	12	13	14	15	16	PC
Crassuletea connatae																		
Muhlenbergia peruviana	1	.	1	.	1	1	67	.	.	.	.	.	.	.	.	.	.	.
Crassula connata	1	1	1	.	.	1	67	.	.	.	.	.	.	.	.	.	.	.
Tagetes multiflora	1	1	1	.	.	1	67	.	.	.	.	.	.	.	.	.	.	.
Calamagrostietea vicunarum																		
Gomphrena meyeniana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chersodoma jodopappa	.	.	.	.	.	.	.	3	4	2	3	.	.	.	.	.	.	40
Clinopodium bolivianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sisyrinchium rigidifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis vicunarum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Parastrephia quadrangularis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca dolichophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Baccharis tricuneata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tetraglochin cristatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago sericea var. *lanuginosa*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Wahlenbergia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lobivia maximiliana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ephedra rupestris	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	20
Lophopappus tarapacanus	4	2	.	.	.	.	33	.	.	.	.	.	.	.	.	.	.	.
Triniochloa stipoides	.	.	.	.	2	.	17	.	.	.	.	.	.	.	.	.	.	.
Philibertia lysimachioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Azorella compacta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	7	5	30
Calamagrostion minimae																		
Calandrinia acaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus ananeanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Echinopsio-Proustietea																		
Vasquezia oppositifolia	.	.	1	.	1	.	33	.	.	.	.	.	.	.	.	.	.	.
Oreocereus hendriksenianus	.	.	.	.	2	.	17	.	.	.	.	.	.	.	.	.	.	.
Puya ferruginea	.	4	.	.	.	.	17	.	.	.	.	.	.	.	.	.	.	.
Dunalia spinosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caiophora cirsiifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium lacteum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viguiera procumbens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polypodio-Tillandsietea																		
Tillandsia capillaris	1	.	1	.	1	1	67	4	4	4	4	.	.	.	.	.	.	40
Companions																		
Stipa ichu	3	1	.	.	3	3	67	.	.	.	.	2	2	3	2	3	2	60
Belloa piptolepis	.	.	.	1	.	.	17	.	.	1	.	1	.	1	1	.	.	40
Galium corymbosum	.	1	1	1	1	.	67	.	1	1	.	.	.	.	.	.	.	20
Nassella inconspicua	.	.	.	.	.	.	.	.	2	.	2	.	.	.	.	.	.	20
Paronychia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bromus catharticus	.	.	.	.	.	.	.	2	1	1	1	.	.	.	.	.	.	40
Cystopteris fragilis	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	20
Cheilanthes pruinata	2	2	1	2	1	1	100	.	.	.	.	.	.	.	.	.	.	.
Hypochaeris meyeniana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Woodsia montevidensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium streptochaetum	1	.	1	1	1	2	83	.	.	.	.	.	.	.	.	.	.	.
Oxalis megalorrhiza	.	1	1	1	1	.	67	.	1	1	1	.	.	.	.	.	.	30
Stevia mandonii	.	.	.	.	.	.	.	3	3	.	3	.	.	.	.	.	.	30
Descurainia depressa	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	.	30
Cardionema ramosissimum	.	.	1	1	1	1	67	.	.	.	.	.	.	.	.	.	.	.
Achyrocline ramosissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aristeguietia ballii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coreopsis fasciculata	.	.	.	.	2	2	33	.	.	.	.	.	.	.	.	.	.	.
Spergularia fasciculata	.	.	.	2	.	.	17	.	.	.	.	.	.	.	.	.	.	.
Bartsia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calceolaria lobata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene genovevae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Achyrocline alata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Descurainia myriophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solanum bukasovii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium subspicatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana interrupta	2	1	.	1	.	.	50	.	1	1	1	.	.	.	.	.	.	30
Bowlesia lobata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa sp.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bartsia crenoloba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gamochaeta purpurea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brayopsis calycina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brayopsis monimocalyx	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyperus seslerioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ourisia muscosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana radicata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aristida adscencionis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Sites: 1–6 Qellepunku, Camata locality, Ubinas district; 7–9, 13–16 Condorwasi, Yanahuara locality, Ichuña district; 10–13 Tolapampa, Ichuña district; 17–22 Sefincane, Ichuña district; 23–26 Cueva en Sura, Yunga locality and district; 27–35 alturas de Pampilla, Pampilla locality, Yunga district; 36–39, 42–47 Punku, Tassa locality, Ubinas district; 40–41, 48–50 Patune, Camata locality, Ubinas district; 51–58 Qasullama, Yunga locality and district.

17	18	19	20	21	22	PC	23	24	25	26	27	28	29	30	31	PC	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	PC
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3	2	2	2	2	2	100	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	27
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Appendix 4. *Baccharido tricuneatae-Puyetum raimondii* (*Azorello-Festucion*) and its four subassociations in the Moquegua region (type relevés underlined).

# Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	PC
Size (m²)	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	
Altitude (x10)	395	409	390	393	414	385	411	402	403	386	386	403	413	387	403	
Slope (°)	45	50	45	40	55	40	45	10	40	45	45	40	80	40	40	
Aspect	E	E	E	E	E	SW	SE	E	W	SW	SW	W	SW	SW	W	
pH	6.6	5.3	6.5	5.6	4.4	6.1	5.0	4.4	-	6.0	5.6	-	-	5.4	-	
Rocks %	0	20	10	20	25	10	20	15	95	25	0	95	95	20	95	
Stones %	40	30	30	30	40	80	40	55	5	45	80	10	5	50	10	
Grazing (0-3)	1	1	1	1	0	0	1	1	1	0	0	1	0	0	2	
Manure (%)	1	1	1	2	0	0	0	0	1	1	0	0	0	0	1	
Vegetation Cover %	65	70	75	60	75	50	65	70	80	75	70	65	60	70	55	
# species	31	32	34	31	40	25	30	37	45	43	38	35	32	38	32	
Calamagrostietea vicunarum																
Calamagrostis vicunarum	.	.	.	.	1	.	.	.	2	.	.	2	2	1	2	40
Parastrephietalia lepidophyllae																
Parastrephia quandrangularis	4	4	4	4	4	4	3	2	3	3	3	2	4	4	2	100
Cumulopuntia boliviana subsp. *ignescens*	2	2	2	2	.	.	.	2	3	2	1	2	.	2	.	67
Tetraglochin cristatum	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	7
Ephedra rupestris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca dolichophylla	4	3	4	4	3	2	2	.	3	2	2	4	4	2	3	93
Baccharis tricuneata	3	4	3	2	3	3	1	3	2	3	3	1	.	2	2	93
Chersodoma jodopappa	3	2	4	3	2	3	2	3	.	3	1	2	2	2	.	87
Plantago sericea var. *lanuginosa*	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	7
Gomphrena meyeniana	1	2	1	2	.	.	.	1	1	.	.	1	.	.	.	47
+Azorello compactae-Festucion orthophyllae																
Lepechinia meyenii	.	.	.	.	.	.	.	3	2	.	.	.	.	.	2	20
Tarasa nototrichoides	.	.	.	.	.	.	.	.	1	1	.	1	1	1	1	40
Philibertia lysimachioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypochaeris chillensis	.	2	.	1	1	.	.	.	1	2	.	1	.	.	1	47
Oxalis calachaccensis	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	7
Conyza deserticola	.	.	.	1	1	.	.	.	.	3	.	.	.	.	.	20
Geranium sessiliflorum	.	.	.	.	.	.	.	.	1	1	2	1	2	3	1	47
Belloa longifolia	.	.	.	.	2	.	.	.	.	1	.	.	1	1	.	27
Lobivia maximiliana	2	.	.	2	.	.	.	.	2	2	2	.	.	2	2	47
Clinopodium bolivianum	.	.	1	1	1	1	2	.	3	3	2	.	.	.	.	53
Sisyrinchium rigidifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Adesmia spinosissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Wahlenbergia peruviana	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	7
Stenomesson sp. (# 3871)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Baccharido tricuneatae-Puyetum raimondii																
Puya raimondii	4	.	4	.	4	4	4	4	4	4	4	4	4	4	4	87
Mutisia orbignyana	3	4	3	.	4	.	.	.	4	3	4	4	4	3	4	73
Alstroemeria pygmaea	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	53
Lupinus paruroensis	.	2	.	.	3	.	.	4	1	.	.	.	1	.	.	33
Baccharis genistelloides	.	.	.	.	1	.	2	.	2	.	.	.	.	.	.	20
Lophopappus tarapacanus	.	3	.	3	.	.	.	4	.	.	.	.	.	.	.	20
Euphorbia huanchahana	.	.	.	.	.	.	.	.	2	1	2	.	2	2	2	40
Solanum fragile	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	7
senecionetosum ferreyrae																
Ageratina azangaroensis	3	3	4	3	2	.	2	.	2	1	2	2	2	2	1	87
Bomarea involucrosa	.	.	.	.	2	2	.	.	2	2	.	2	.	1	.	40
Stevia macbridei	3	3	3	2	2	2	3	.	.	2	.	.	.	.	.	53
Senecio ferreyrae	.	.	1	.	.	2	.	1	3	2	2	2	3	2	2	67
Triniochloa stipoides	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	20
Aphanes andicola	.	.	.	.	.	.	.	.	.	1	1	.	.	1	.	20
Solanum chamaesarachidium	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	13
Escallonia myrtilloides	.	.	.	.	.	.	.	.	.	.	.	4	.	.	4	13
ageratinetosum sternbergianae																
Ageratina sternbergiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Weberbauera peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca orthophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stevia mandonii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

# Relevé	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	PC
Size (m²)	36	36	36	36	36	36	36	150	36	36	36	36	36	36	36	36	36	36	36	
Altitude (x10)	402	406	392	401	386	386	415	419	386	418	415	418	417	416	418	387	389	419	389	
Slope (°)	65	10	45	48	80	60	40	30	80	45	40	45	45	30	35	70	40	60	40	
Aspect	SW	SW	E	SW	S	S	NE	E	S	E	NE	E	E	E	E	NE	NW	NW	NW	
pH	5.4	5.8	6.6	4.6	4.6	4.9	5.4	6.5	4.9	5.0	5.1	5.6	5.2	5.4	5.4	4.8	5.5	5.0	5.0	
Rocks %	80	70	30	65	85	85	25	55	85	15	55	30	20	30	25	80	65	90	60	
Stones %	20	20	45	30	10	10	50	20	10	58	30	50	55	40	35	40	25	15	20	
Grazing (0-3)	0	0	1	1	1	1	2	0	1	2	1	1	1	1	1	0	1	0	0	
Manure (%)	0	0	1	0	1	0	0	2	2	1	0	1	0	1	1	0	1	0	0	
Vegetation Cover %	80	75	75	80	65	45	80	45	75	80	65	65	70	50	60	70	80	50	75	
# species	46	40	48	43	34	26	45	25	43	54	36	35	47	15	30	46	39	30	44	
Calamagrostietea vicunarum																				
Calamagrostis vicunarum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	11
Parastrephietalia lepidophyllae																				
Parastrephia quandrangularis	2	3	.	.	.	4	3	2	3	2	3	3	2	.	.	.	.	.	3	58
Cumulopuntia boliviana subsp. *ignescens*	2	.	.	.	.	.	2	.	2	2	2	.	2	.	2	2	.	2	2	53
Tetraglochin cristatum	2	.	.	2	3	.	3	.	2	3	2	.	.	.	.	.	.	.	.	37
Ephedra rupestris	.	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.	.	11
Festuca dolichophylla	4	3	3	2	.	.	2	3	3	2	2	3	3	.	1	2	2	.	3	79
Baccharis tricuneata	2	3	2	3	4	.	3	2	3	2	2	3	2	1	3	1	2	.	2	90
Chersodoma jodopappa	2	3	3	2	.	2	2	.	2	2	2	1	.	2	2	1	3	.	2	79
Plantago sericea var. *lanuginosa*	1	1	2	.	.	2	2	2	1	.	.	.	.	.	.	2	2	1	1	58
Gomphrena meyeniana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	.	2	16
+Azorello compactae-Festucion orthophyllae																				
Lepechinia meyenii	.	3	2	.	.	.	.	.	2	2	.	4	2	.	3	.	.	.	.	37
Tarasa nototrichoides	.	.	.	.	.	.	1	1	1	2	1	1	1	1	2	1	.	1	2	63
Philibertia lysimachioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	2	21
Hypochaeris chillensis	.	.	.	.	.	.	2	2	2	1	2	.	2	.	1	2	.	.	2	47
Oxalis calachaccensis	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	.	.	.	.	21
Conyza deserticola	.	3	2	.	.	.	2	.	1	1	.	.	2	.	.	1	3	.	.	42
Geranium sessiliflorum	2	2	2	.	.	.	1	.	2	1	.	.	2	.	.	.	.	.	.	37
Belloa longifolia	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16
Lobivia maximiliana	2	2	2	.	.	2	2	2	3	2	2	.	.	.	.	2	4	2	2	68
Clinopodium bolivianum	.	.	.	4	4	.	2	.	3	1	1	.	2	.	1	.	.	.	.	42
Sisyrinchium rigidifolium	.	.	.	.	.	.	.	.	3	1	.	.	2	.	.	.	.	.	.	16
Adesmia spinosissima	.	.	.	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	16
Wahlenbergia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stenomesson sp. (# 3871)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Baccharido tricuneatae-Puyetum raimondii																				
Puya raimondii	.	.	.	4	.	.	4	4	5	4	4	4	5	4	4	4	4	4	4	74
Mutisia orbignyana	2	.	2	.	.	.	.	.	.	3	.	3	1	.	.	.	.	2	2	37
Alstroemeria pygmaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus paruroensis	3	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	3	26
Baccharis genistelloides	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
Lophopappus tarapacanus	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	2	4	2	4	26
Euphorbia huanchahana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solanum fragile	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	11
senecionetosum ferreyrae																				
Ageratina azangaroensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bomarea involucrosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stevia macbridei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio ferreyrae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Triniochloa stipoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aphanes andicola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solanum chamaesarachidium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Escallonia myrtilloides	.	.	.	.	.	.	.	.	.	.	.	4	.	.	4	.	.	.	.	11
ageratinetosum sternbergianae																				
Ageratina sternbergiana	2	3	2	3	.	1	2	.	1	2	1	3	2	.	2	.	.	.	.	63
Weberbauera peruviana	1	2	2	.	2	1	.	1	.	2	.	2	1	1	2	2	1	.	1	74
Festuca orthophylla	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
Stevia mandonii	.	1	1	1	3	.	3	.	2	2	2	2	2	.	2	2	2	1	.	74

# Relevé	35	36	37	38	39	40	41	42	43	44	PC	45	46	47	48	49	50	51	PC
Size (m²)	36	36	36	36	36	36	36	36	36	36		36	36	36	36	36	36	36	
Altitude (x10)	429	429	450	429	442	442	442	442	442	442		408	404	402	407	403	403	403	
Slope (°)	30	30	20	30	20	20	20	20	20	20		40	35	40	40	40	35	35	
Aspect	NE	NE	S	NE	N	N	N	N	N	N		NNE	NE	W	N	NW	NW	W	
pH	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	
Rocks %	10	10	10	10	15	20	15	10	10	10		5	10	5	15	10	10	10	
Stones %	10	10	10	10	10	10	12	10	10	10		10	15	10	10	10	15	10	
Grazing (0-3)	2	2	0	1	2	2	2	2	2	2		2	2	1	1	1	1	1	
Manure (%)	1	2	1	1	1	1	1	2	1	1		3	3	2	1	1	0	1	
Vegetation Cover %	65	50	60	65	55	55	50	50	60	55		50	55	55	50	40	40	50	
# species	36	27	31	36	30	27	23	28	28	23		31	32	36	29	28	26	24	
Calamagrostietea vicunarum																			
Calamagrostis vicunarum	2	3	3	2	1	2	1	2	2	3	100	.	.	.	.	.	.	.	.
Parastrephietalia lepidophyllae																			
Parastrephia quandrangularis	3	4	.	4	4	4	4	4	4	4	90	4	2	.	.	1	2	4	71
Cumulopuntia boliviana subsp. *ignescens*	3	.	3	2	1	3	.	3	2	.	70	.	.	.	2	2	1	2	57
Tetraglochin cristatum	.	.	.	.	4	2	4	2	3	2	60	.	.	.	.	2	.	1	29
Ephedra rupestris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	14
Festuca dolichophylla	4	.	4	.	4	5	5	5	5	5	80	.	.	.	.	.	.	.	.
Baccharis tricuneata	2	4	.	3	3	4	2	3	4	2	90	.	1	1	4	2	.	.	57
Chersodoma jodopappa	.	.	2	.	.	.	.	.	.	.	10	.	2	1	.	.	.	4	43
Plantago sericea var. *lanuginosa*	.	.	1	.	1	.	1	1	1	1	60	.	.	.	.	.	.	2	14
Gomphrena meyeniana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
+Azorello compactae-Festucion orthophyllae																			
Lepechinia meyenii	.	.	.	.	.	.	.	.	.	.	.	2	2	2	2	1	2	2	100
Tarasa nototrichoides	1	1	.	1	1	1	.	1	.	.	60	1	1	1	1	1	1	.	86
Philibertia lysimachioides	.	.	.	.	.	.	.	.	.	.	.	.	4	1	.	.	.	.	29
Hypochaeris chillensis	1	.	.	1	.	.	.	.	.	.	20	1	2	2	2	1	1	.	86
Oxalis calachaccensis	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	1	.	57
Conyza deserticola	1	1	1	2	1	1	.	1	1	.	80	.	.	.	1	1	1	1	57
Geranium sessiliflorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa longifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lobivia maximiliana	2	2	3	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.
Clinopodium bolivianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sisyrinchium rigidifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	14
Adesmia spinosissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Wahlenbergia peruviana	.	.	2	.	.	2	.	1	2	.	40	.	.	.	.	.	.	.	.
Stenomesson sp. (# 3871)	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	29
Baccharido tricuneatae-Puyetum raimondii																			
Puya raimondii	4	4	4	4	4	3	4	4	4	4	100	4	4	4	4	4	4	4	100
Mutisia orbignyana	4	.	.	4	.	.	.	.	.	.	20	.	4	.	.	.	.	.	14
Alstroemeria pygmaea	1	1	1	1	.	.	.	.	.	.	40	1	1	1	1	2	1	.	86
Lupinus paruroensis	4	4	4	4	1	.	1	.	2	2	80	4	4	4	4	5	5	4	100
Baccharis genistelloides	.	.	.	.	.	2	3	.	.	3	30	.	.	.	.	.	.	.	.
Lophopappus tarapacanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	14
Euphorbia huanchahana	1	1	1	1	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.
Solanum fragile	.	.	.	1	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.
senecionetosum ferreyrae																			
Ageratina azangaroensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bomarea involucrosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stevia macbridei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio ferreyrae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Triniochloa stipoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aphanes andicola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solanum chamaesarachidium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Escallonia myrtilloides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
ageratinetosum sternbergianae																			
Ageratina sternbergiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Weberbauera peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca orthophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stevia mandonii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

# Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	PC
lupinetosum cuzcensis																
Lupinus cuzcensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio nutans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus sp. 1(# 3713)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxalis nubigena	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Olsynium junceum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis violacea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium dombeyanum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	7
calamagrostietosum heterophyllae																
Viola micranthella	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	7
Poa gymnantha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis heterophylla	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	7
Stipa obtusa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anthochloo-Dielsiochloetea																
Bougueria nubicola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostion minimae																
Calandrinia acaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus ananeanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crassuletea connatae																
Muhlenbergia peruviana	.	.	.	.	.	.	.	1	.	1	2	.	1	1	.	33
Tagetes multiflora	.	2	2	.	.	.	.	.	1	1	.	1	1	2	1	53
Crassula connata	.	.	.	.	.	.	.	1	1	.	.	1	1	.	.	27
Mancoa hispida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Argyrochosmetea niveae																
Luzula racemosa	2	2	2	.	.	2	3	.	.	.	.	.	.	.	.	33
Cheilanthes pilosa	.	.	.	.	1	1	2	.	.	2	2	.	.	1	.	40
Bomarea dulcis	1	1	2	1	.	.	.	.	.	.	.	3	.	.	2	40
Salpichroa glandulosa	.	.	.	.	2	.	.	.	2	3	2	2	.	3	.	40
Hypochaeris mucida	.	.	.	.	1	3	2	.	.	.	.	.	.	.	.	20
Loricaria graveolens	.	.	.	.	2	3	4	.	.	.	1	.	.	.	.	27
Senecio sublutescens	.	2	.	.	1	.	3	.	.	2	.	.	.	2	.	33
Neowerdermannia peruviana	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	7
Plantago sericea	1	2	3	.	.	.	.	.	.	.	.	.	.	.	.	20
Spergularia andina	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	13
Peperomia scutellaefolia	.	.	.	2	.	.	.	.	1	.	.	.	1	1	.	27
Belloa kunthiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa schultzii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polystichum orbiculatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana nivalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ribes brachybothrys	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	7
Pellaea ternifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Argyrochosma nivea	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	7
Echinopsio-Proustietea																
Vasquezia oppositifolia	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	7
Gnaphalium lacteum	.	.	.	.	1	2	1	.	.	.	.	.	1	.	.	27
Viguiera procumbens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia setigera	2	1	1	1	.	.	.	.	.	.	.	.	.	.	.	27
Philibertia solanoides	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	13
Soncho-Bidentetea pilosi																
Trifolium amabile	.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	13
Polypodio-Tillandsietea																
Tillandsia capillaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Companions																
Stipa ichu	4	.	.	4	4	4	4	4	4	4	4	3	.	4	2	80
Belloa piptolepis	1	2	1	1	1	.	2	1	.	1	1	.	.	1	.	67
Galium corymbosum	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1	100
Nassella inconspicua	.	.	.	.	.	.	.	3	4	.	.	2	.	.	.	20
Hieracium streptochaetum	2	2	2	2	2	2	2	2	1	2	2	.	.	2	1	87
Bromus catharticus	.	.	.	.	1	2	2	.	1	1	2	1	.	2	.	53
Cheilanthes pruinata	3	3	3	2	3	.	2	2	2	1	3	2	3	3	2	93
Woodsia montevidensis	1	1	2	1	.	1	2	.	1	1	2	.	2	1	1	80
Calceolaria lobata	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	13
Hypochaeris meyeniana	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	7
Bartsia peruviana	2	2	2	2	.	.	.	1	.	2	1	.	.	.	.	47
Calceolaria inamoena	3	.	.	.	.	.	.	2	2	.	2	2	3	.	1	47
Cyperus seslerioides	2	2	1	2	.	.	.	2	1	.	.	1	.	.	1	53
Cardionema ramosissimum	1	1	2	1	.	.	.	1	1	.	.	1	2	.	1	60
Valeriana interrupta	3	3	2	2	3	.	.	2	2	.	2	2	.	2	2	73

# Relevé	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	PC
lupinetosum cuzcensis																				
Lupinus cuzcensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio nutans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus sp. 1(# 3713)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxalis nubigena	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Olsynium junceum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis violacea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium dombeyanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
calamagrostietosum heterophyllae																				
Viola micranthella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa gymnantha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis heterophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stipa obtusa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anthochloo-Dielsiochloetea																				
Bougueria nubicola	.	.	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	16
Calamagrostion minimae																				
Calandrinia acaulis	1	1	2	1	2	.	1	.	.	.	1	.	.	.	.	1	.	1	.	47
Lupinus ananeanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crassuletea connatae																				
Muhlenbergia peruviana	.	.	.	.	.	.	2	1	1	1	2	1	1	1	3	2	3	2	1	68
Tagetes multiflora	2	1	2	.	.	.	1	1	1	1	1	1	1	.	1	2	2	1	2	79
Crassula connata	1	2	2	.	.	.	.	.	1	1	.	.	1	.	2	.	.	.	.	37
Mancoa hispida	.	3	2	.	.	.	.	.	.	.	.	2	.	.	1	.	.	.	.	21
Argyrochosmetea niveae																				
Luzula racemosa	2	2	2	2	2	2	.	.	.	.	.	.	.	1	.	2	.	2	2	53
Cheilanthes pilosa	3	2	1	1	3	4	.	.	1	.	.	1	1	2	.	1	2	2	2	74
Bomarea dulcis	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
Salpichroa glandulosa	3	3	3	2	.	.	.	.	.	2	.	2	1	.	2	2	.	2	2	58
Hypochaeris mucida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Loricaria graveolens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio sublutescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	5
Neowerdermannia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago sericea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Peperomia scutellaefolia	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1	1	21
Belloa kunthiana	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26
Belloa schultzii	2	.	.	2	1	.	.	.	.	.	.	.	.	2	.	.	.	.	.	21
Polystichum orbiculatum	2	1	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
Valeriana nivalis	4	2	3	2	3	.	1	.	.	1	.	.	.	.	.	.	.	.	.	37
Ribes brachybothrys	4	4	4	3	.	.	.	.	.	2	.	3	.	.	.	4	2	.	3	47
Pellaea ternifolia	.	.	.	1	.	.	2	.	1	.	.	.	.	.	.	.	1	.	1	26
Argyrochosma nivea	.	.	.	1	1	.	.	.	1	.	.	1	.	.	.	.	.	.	1	26
Echinopsio-Proustietea																				
Vasquezia oppositifolia	.	.	.	.	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	16
Gnaphalium lacteum	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	5
Viguiera procumbens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	2	16
Paronychia setigera	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
Philibertia solanoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Soncho-Bidentetea pilosi																				
Trifolium amabile	.	.	.	3	3	.	2	.	2	.	.	.	.	.	.	.	.	.	.	21
Polypodio-Tillandsietea																				
Tillandsia capillaris	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	3	.	2	.	21
Companions																				
Stipa ichu	.	.	.	4	.	2	4	4	4	3	4	4	4	1	4	2	4	2	.	74
Belloa piptolepis	1	3	2	1	2	.	2	2	1	1	2	.	2	.	2	.	.	1	.	68
Galium corymbosum	2	1	1	1	1	1	2	1	.	.	2	.	1	.	.	1	2	.	1	68
Nassella inconspicua	2	3	2	1	1	1	2	2	1	1	2	1	2	.	1	2	2	3	2	95
Hieracium streptochaetum	2	2	2	1	3	2	2	2	3	2	2	2	1	2	1	2	3	2	2	100
Bromus catharticus	2	.	2	2	1	.	1	.	.	.	1	1	1	.	2	1	1	.	1	63
Cheilanthes pruinata	1	.	3	1	1	1	1	2	3	1	2	1	1	1	1	2	1	1	1	95
Woodsia montevidensis	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	16
Calceolaria lobata	3	2	2	.	.	1	.	.	.	.	.	.	.	.	.	1	1	.	1	37
Hypochaeris meyeniana	3	2	2	3	3	.	3	.	2	1	1	1	2	2	2	.	2	.	.	74
Bartsia peruviana	1	.	2	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	21
Calceolaria inamoena	.	.	.	.	.	.	.	.	.	2	.	1	1	.	.	.	.	.	.	16
Cyperus seslerioides	2	1	1	.	.	.	2	2	2	1	2	2	1	.	.	1	3	2	1	74
Cardionema ramosissimum	1	1	1	.	.	.	2	2	1	1	2	.	.	.	.	1	1	2	1	63
Valeriana interrupta	2	.	2	2	2	.	1	.	2	1	2	2	1	.	.	1	1	2	2	74

# Relevé	35	36	37	38	39	40	41	42	43	44	PC	45	46	47	48	49	50	51	PC
lupinetosum cuzcensis																			
Lupinus cuzcensis	1	2	1	.	3	2	3	2	3	3	90	.	.	.	.	.	.	.	.
Senecio nutans	2	.	.	2	3	4	2	3	4	5	80	.	.	.	.	.	.	.	.
Lupinus sp. 1(# 3713)	.	.	.	.	1	2	1	2	.	3	50	.	.	.	.	.	.	.	.
Oxalis nubigena	1	.	1	1	1	1	1	1	1	1	90	.	.	.	.	.	.	.	.
Olsynium junceum	1	1	1	1	1	.	.	1	1	.	70	.	.	.	.	.	.	.	.
Calamagrostis violacea	1	1	1	.	1	.	1	.	1	1	70	.	.	.	.	.	.	.	.
Gnaphalium dombeyanum	1	.	2	1	1	1	.	1	2	.	70	.	.	.	.	.	.	.	.
calamagrostietosum heterophyllae																			
Viola micranthella	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	100
Poa gymnantha	.	.	1	.	.	.	.	.	.	.	10	1	1	2	.	1	1	1	86
Calamagrostis heterophylla	.	.	.	.	.	.	.	.	.	.	.	2	.	1	1	2	.	1	71
Stipa obtusa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	43
Anthochloo-Dielsiochloetea																			
Bougueria nubicola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostion minimae																			
Calandrinia acaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus ananeanus	.	.	.	.	1	.	1	.	2	1	40	.	.	.	.	.	.	.	.
Crassuletea connatae																			
Muhlenbergia peruviana	1	1	1	.	1	1	1	1	1	1	90	1	1	1	1	1	1	1	100
Tagetes multiflora	1	.	.	1	.	.	.	.	.	.	20	1	1	1	.	.	.	.	43
Crassula connata	1	1	.	1	.	.	.	.	.	.	30	1	.	1	1	.	1	.	57
Mancoa hispida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	14
Argyrochosmetea niveae																			
Luzula racemosa	.	.	.	.	1	1	.	1	1	.	40	.	.	.	.	.	.	.	.
Cheilanthes pilosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bomarea dulcis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salpichroa glandulosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypochaeris mucida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Loricaria graveolens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio sublutescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neowerdermannia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago sericea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Peperomia scutellaefolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa kunthiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa schultzii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polystichum orbiculatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana nivalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ribes brachybothrys	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pellaea ternifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Argyrochosma nivea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Echinopsio-Proustietea																			
Vasquezia oppositifolia	.	.	1	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.
Gnaphalium lacteum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viguiera procumbens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia setigera	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	29
Philibertia solanoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Soncho-Bidentetea pilosi																			
Trifolium amabile	.	.	1	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.
Polypodio-Tillandsietea																			
Tillandsia capillaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Companions																			
Stipa ichu	4	4	4	4	4	4	4	4	4	4	100	4	4	4	4	4	4	4	100
Belloa piptolepis	.	.	.	.	1	1	1	1	1	1	60	.	.	.	.	.	.	2	14
Galium corymbosum	1	1	1	1	1	1	1	1	1	1	100	1	1	1	1	1	1	1	100
Nassella inconspicua	4	2	4	4	2	3	2	2	3	3	100	3	3	4	4	3	3	.	86
Hieracium streptochaetum	1	1	2	2	2	.	2	.	.	3	70	2	2	2	1	2	.	2	86
Bromus catharticus	.	.	.	.	2	1	.	1	2	.	40	.	.	.	.	.	.	.	.
Cheilanthes pruinata	1	2	1	1	.	.	.	.	.	.	40	1	.	1	1	1	.	.	57
Woodsia montevidensis	1	1	1	1	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.
Calceolaria lobata	2	2	.	2	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.
Hypochaeris meyeniana	2	2	2	2	2	2	2	2	2	2	100	1	1	1	.	.	1	2	71
Bartsia peruviana	.	1	.	1	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.
Calceolaria inamoena	.	2	.	.	.	.	.	.	.	.	10	4	.	.	.	.	.	.	14
Cyperus seslerioides	.	.	.	.	.	.	.	.	.	.	.	1	2	2	1	1	1	1	100
Cardionema ramosissimum	.	.	1	.	.	.	.	.	.	.	10	.	.	.	.	.	.	1	14
Valeriana interrupta	.	.	.	.	.	.	.	.	.	.	.	1	2	2	.	.	.	.	

# Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	PC	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	PC	35	36	37	38	39	40	41	42	43	44	PC	45	46	47	48	49	50	51	PC
Oxalis megalorrhiza	.	.	.	.	1	1	2	.	.	1	1	.	1	2	.	47	1	2	1	1	1	.	1	.	1	1	.	2	1	.	.	.	.	.	.	53	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	14
Achyrocline ramosissima	.	.	.	.	2	1	3	2	2	2	.	2	2	.	2	60	.	.	.	2	.	2	2	2	1	2	2	.	2	.	.	2	2	.	1	58	.	.	2	.	.	.	.	.	.	.	10	1	1	2	2	1	1	2	100
Bartsia crenoloba	.	.	.	.	1	.	1	1	.	1	1	.	1	1	.	47	3	1	2	2	3	.	1	1	1	1	1	1	2	.	.	2	2	.	1	79	1	.	.	1	.	1	.	1	1	.	50	1	1	1	.	.	2	.	57
Cerastium subspicatum	1	1	2	.	1	.	1	.	1	.	.	.	.	.	1	47	.	1	1	1	2	.	1	.	.	2	.	.	1	.	.	.	.	.	.	37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bidens andicola	2	2	2	1	2	.	.	2	2	.	.	1	.	.	.	53	.	.	.	1	2	.	2	.	1	2	2	2	1	.	.	2	1	2	3	63	.	.	.	2	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.
Facelis plumosa	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	20	.	1	1	.	.	2	1	2	2	1	1	1	1	1	2	1	1	.	1	79	1	1	.	1	.	.	.	.	.	.	30	.	1	1	.	.	.	.	29
Galinsoga mandonii	.	.	.	.	.	.	.	.	1	1	.	.	.	1	1	27	.	.	.	.	.	.	.	.	.	1	.	1	1	.	1	1	2	2	1	42	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	43
Gnaphalium americanum	.	2	.	.	2	1	1	.	.	.	.	.	.	.	.	27	.	.	.	.	.	.	1	.	.	.	1	.	1	.	2	.	2	.	1	32	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Laennecia artemisioides	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	.	86
Achyrocline alata	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	7	2	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1	1	.	.	26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gamochaeta purpurea	.	.	1	.	1	1	2	2	.	1	.	.	.	.	.	40	.	1	.	.	.	1	1	.	.	1	1	.	.	.	.	.	.	.	.	26	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	.	1	1	71
Solanum bukasovii	.	.	.	.	.	.	.	.	1	2	2	.	.	2	.	27	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	14
Bowlesia lobata	.	.	.	.	.	.	.	.	.	2	1	.	.	1	.	20	2	1	2	1	1	.	.	1	.	1	.	.	1	.	1	2	1	.	1	63	1	.	.	1	.	.	.	.	.	.	20	1	1	1	1	1	.	.	71
Perezia pungens	2	.	2	3	1	2	2	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asplenium peruvianum	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	7	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia fasciculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	.	.	1	1	.	.	1	.	.	.	.	.	.	32	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cheilanthes arequipensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2	2	2	.	.	.	.	.	.	.	.	.	1	1	1	.	37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Microsteris gracilis	.	.	.	.	.	.	.	1	.	.	.	.	1	.	1	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	100	1	1	1	1	1	1	.	86
Gilia laciniata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	.	1	.	1	2	60	1	1	1	1	1	1	.	86
Aristeguietia ballii	.	.	.	.	.	.	.	.	1	.	.	1	1	.	1	27	.	.	.	.	.	.	1	1	.	1	2	.	1	1	.	.	.	.	.	32	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana radicata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.
Ourisia muscosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	.	30	.	.	.	.	.	.	.	.
Quinchamalium procumbens	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia andina	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	7	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Descurainia depressa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis nigricans	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Geranium core-core	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ephedra americana	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium aparine	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	7	.	.	.	.	1	1	1	.	.	1	.	.	.	.	.	.	.	.	.	21	.	.	.	1	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.
Castilleja arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Sites: 1–15 Qasullama, Yunga locality and district; 16–19, 22–23, 25–30, 33 Santa Cruz de Oyo Oyo, Ichuña district; 20–21, 24, 31–32, 34 Rocky slopes near Ichuña locality, Ichuña district; 35–41Punku-Rancho, Tassa locality, Ubinas district; 42–51Sura, Yunga locality and district.

Appendix 5. Grassland communities (*Sisyrinchio rigidifolii-Parastrephietum quadrangularis, Azorello-Festucion* and *Baccharido caespitosae-Azorelletum diapensioidis, Calamagrostion minimae*) in the Moquegua region at 3940–4470 m (type relevés are underlined).

# Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	PC
Size (m²)	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	
Altitude (x10)	404	401	404	404	404	403	405	405	411	398	404	394	398	395	394	402	398	397	396	401	
Slope (°)	25	25	25	25	25	35	35	30	45	45	30	55	40	40	30	40	40	45	40	40	
Aspect	ESE	SE	ESE	ESE	ESE	E	E	E	N	NE	E	E	NE	NE	E	NE	NE	NE	NE	NE	
pH	-	-	-	-	-	7.4	5.9	6.1	6.1	6.6	5.6	6.6	6.1	7.0	7.5	6.6	7.0	7.2	6.6	6.9	
Rocks %	25	40	20	30	20	30	10	35	5	20	35	20	15	15	15	20	15	10	10	10	
Stones %	15	2	15	15	15	40	45	25	20	20	25	40	30	30	30	70	20	40	30	60	
Grazing (0-3)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	2	1	1	1	
Manure (0-3)	0	1	1	0	1	1	1	1	1	1	2	1	1	1	1	2	2	1	2	1	
Vegetation Cover %	70	65	70	80	70	85	70	80	80	80	85	80	80	80	75	75	75	80	80	75	
# species	34	45	37	36	32	32	38	37	33	35	22	30	30	31	27	22	30	32	33	32	
Calamagrostietea vicunarum																					
Calamagrostis vicunarum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	10
Parastrephietalia lepidophyllae																					
Parastrephia quadrangularis	4	4	5	4	3	4	4	3	3	4	3	4	4	3	4	4	4	3	4	4	100
Tetraglochin cristatum	.	3	2	2	.	2	2	.	.	2	.	.	1	.	.	.	.	.	.	2	40
Cumulopuntia boliviana subsp. *ignescens*	2	3	2	.	.	3	2	2	3	2	.	.	2	.	2	3	2	4	2	2	75
Ephedra rupestris	2	2	.	1	2	2	2	.	1	.	.	4	2	.	.	2	.	.	.	.	50
Baccharis tricuneata	3	4	2	.	3	4	4	4	.	3	.	2	3	1	.	.	3	4	2	3	75
Festuca dolichophylla	4	3	4	4	2	.	.	.	.	2	.	.	3	.	.	.	2	2	2	.	50
Chersodoma jodopappa	.	.	.	.	.	4	4	4	4	3	.	3	3	4	2	.	3	3	3	2	65
Plantago sericea var. *lanuginosa*	.	.	.	.	.	2	1	1	1	.	.	.	.	.	.	.	.	.	.	.	20
Gomphrena meyeniana	.	2	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
+Azorello compactae-Festucion orthophyllae																					
Tarasa nototrichoides	1	1	1	1	1	2	1	1	2	2	2	1	1	1	2	1	1	2	2	1	100
Conyza deserticola	1	1	1	1	1	.	1	3	2	3	4	2	.	.	2	2	2	2	2	3	85
Hypochaeris chillensis	2	1	1	2	1	.	2	3	4	2	.	.	2	2	2	2	2	2	2	2	85
Lepechinia meyenii	3	3	.	4	2	4	2	.	.	.	.	.	.	4	.	.	.	.	4	.	40
Philibertia lysimachioides	.	3	2	4	.	.	.	.	.	2	1	1	2	.	.	.	.	1	1	2	50
Lupinus paruroensis	.	.	.	.	.	2	2	2	4	.	.	.	.	.	.	.	.	.	.	.	20
Belloa longifolia	1	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
Wahlenbergia peruviana	2	2	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
Lobivia maximiliana	.	.	.	.	.	3	.	2	.	.	.	2	.	2	2	.	.	.	.	.	25
Geranium sessiliflorum	.	.	.	.	.	.	1	2	2	.	.	.	.	2	.	.	.	.	.	.	20
Oxalis calachaccensis	.	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	.	1	.	15
Oxalis nubigena	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25
Senecio evacoides	3	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15
Viola micranthella	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
Adesmia spinosissima	.	.	.	.	.	.	.	.	.	.	.	3	.	2	1	.	.	.	.	.	15
Mutisia orbignyana	.	.	.	.	.	3	4	3	4	.	.	.	.	.	.	.	.	.	.	.	20
Ageratina sternbergiana	.	.	.	.	.	.	.	.	.	.	.	2	.	4	.	.	.	4	4	.	20
Euphorbia huanchahana	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Gnaphalium dombeyanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sisyrinchio rigidifolii-Parastrephietum quadrangularis																					
Sisyrinchium rigidifolium	3	2	2	2	2	2	1	3	1	2	1	3	2	2	1	1	2	2	2	2	100
Silene genovevae	.	2	.	2	2	2	1	3	2	1	2	.	.	3	2	.	3	2	2	2	75
Caiophora chuquitensis	.	2	2	1	.	.	.	.	.	2	1	2	2	.	.	.	2	1	.	1	50
Astragalus arequipensis	.	1	1	1	.	.	.	.	.	.	.	3	.	1	2	.	.	.	.	.	30
Plantago sp. (Image 0397, 15/04/2012)	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
Ophioglossum crotalophoroides	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15

# Relevé	21	22	23	24	25	26	27	28	29	PC	30	31	32	33	34	35	36	37	38	PC	39	40	41	42	43	44	45	46	47	48	PC
Size (m²)	36	36	36	36	36	36	36	36	36		36	36	36	36	36	36	36	36	36		36	36	36	36	36	36	36	36	36	36	
Altitude (x10)	442	442	442	442	442	442	442	442	442		441	443	442	441	440	440	440	440	439		435	436	437	438	439	447	447	445	443	440	
Slope (°)	35	35	35	35	35	35	35	35	35		10	10	10	10	10	10	10	10	10		10	15	10	10	15	30	35	40	40	35	
Aspect	NE	NE	NE	NE	NE	NE	NE	NE	NE		E	E	E	E	E	E	E	E	E		SW	SW	SW	SW	SW	SE	SE	SE	SE	SE	
pH	-	-	-	-	-	-	-	-	-		4.8	5.1	5.3	5.0	-	4.8	5.5	5.7	5.0		-	-	-	-	-	-	-	-	-	-	
Rocks %	20	20	15	20	20	20	20	15	20		0	0	0	0	0	0	0	0	0		20	15	15	20	10	10	20	20	20	15	
Stones %	10	10	5	10	10	10	10	5	5		15	15	20	15	15	10	15	15	15		10	15	15	10	15	15	15	15	15	15	
Grazing (0-3)	1	2	1	2	2	1	2	1	2		2	3	2	3	3	3	3	4	4		0	0	1	0	0	1	0	0	0	1	
Manure (0-3)	1	2	2	3	2	2	2	1	1		3	3	2	2	3	2	2	3	2		0	0	1	0	1	0	1	0	0	0	
Vegetation Cover %	65	70	70	70	65	70	75	75	70		70	75	75	75	75	80	80	70	75		50	50	55	55	50	60	60	55	60	55	
# species	21	25	24	25	24	23	27	20	23		8	8	7	9	9	8	7	10	9		20	19	18	19	22	29	23	26	24	21	
Calamagrostietea vicunarum																															
Calamagrostis vicunarum	1	.	1	1	.	1	1	1	1	78	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	1	1	.	.	1	70
Parastrephietalia lepidophyllae																															
Parastrephia quadrangularis	4	4	4	4	4	4	4	4	4	100	2	3	.	3	4	2	4	2	2	89	3	3	2	3	3	2	3	3	2	3	100
Tetraglochin cristatum	1	2	2	1	4	4	2	3	2	100	3	2	2	4	2	3	.	4	4	89	2	2	2	2	2	1	2	2	.	2	90
Cumulopuntia boliviana subsp. *ignescens*	.	.	.	.	.	.	.	.	.	.	4	5	.	.	.	.	2	.	1	44	.	2	.	2	.	2	.	.	.	.	30
Ephedra rupestris	.	2	2	2	2	2	2	.	2	78	.	.	.	.	.	.	.	4	.	11	1	.	2	.	2	.	.	2	.	.	40
Baccharis tricuneata	.	4	4	4	4	4	4	4	.	78	.	.	.	.	.	.	.	.	.	.	.	3	.	2	.	3	.	2	.	2	50
Festuca dolichophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	2	2	.	2	.	3	3	70
Chersodoma jodopappa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago sericea var. *lanuginosa*	.	1	1	1	1	1	1	.	1	78	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	100
Gomphrena meyeniana	3	2	2	3	1	1	1	2	.	89	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	.	1	.	1	80
+Azorello compactae-Festucion orthophyllae																															
Tarasa nototrichoides	1	1	1	1	1	1	1	1	1	100	3	1	3	3	2	2	1	.	1	89	.	.	.	.	.	.	.	.	.	.	.
Conyza deserticola	1	.	1	1	.	1	1	1	1	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypochaeris chillensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lepechinia meyenii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Philibertia lysimachioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus paruroensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa longifolia	1	2	.	1	1	.	1	1	.	67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Wahlenbergia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lobivia maximiliana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	10
Geranium sessiliflorum	1	1	1	1	1	1	1	1	2	100	3	2	2	.	2	3	.	3	3	78	.	.	.	.	.	.	.	.	.	.	.
Oxalis calachaccensis	.	1	1	1	1	1	1	.	1	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxalis nubigena	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio evacoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	.	2	40
Viola micranthella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Adesmia spinosissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mutisia orbignyana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ageratina sternbergiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphorbia huanchahana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium dombeyanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	10
Sisyrinchio rigidifolii-Parastrephietum quadrangularis																															
Sisyrinchium rigidifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene genovevae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caiophora chuquitensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	20
Astragalus arequipensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago sp. (Image 0397, 15/04/2012)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
Ophioglossum crotalophoroides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		

# Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	PC	21	22	23	24	25	26	27	28	29	PC	30	31	32	33	34	35	36	37	38	PC	39	40	41	42	43	44	45	46	47	48	PC
Lobivia sp. (Image 0468, 15/04/2012)	.	3	2	4	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hedeoma mandoniana	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oenothera nana	.	.	.	.	.	.	.	.	.	1	.	.	2	1	1	.	.	1	2	2	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bartsia melampyroides	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	2	.	1	2	2	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perezia sublyrata	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	2	.	.	2	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana coarctata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Community of *Misbrookea strigosissima* and *Stipa ichu*																																																				
Senecio rhizocephalus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	1	.	1	1	67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stenomesson sp. (# 3871)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	.	89	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Misbrookea strigosissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	2	2	2	2	2	3	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Belloa sp.1(# 3824)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	.	1	1	1	78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perezia coerulescens	1	2	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	2	.	2	1	.	1	.	1	56	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Community of *Plagiobothrys humilis* and *Stipa ichu*																																																				
Plagiobothrys humilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	1	2	1	.	2	2	78	.	.	.	.	.	.	.	.	.	.	.
Arenaria sp. (# 2272)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	1	1	.	.	56	.	.	.	.	1	1	.	.	.	.	20
Urtica echinata	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	2	2	3	.	56	.	.	.	.	.	.	.	.	.	.	.
+Calamagrostion minimae																																																				
Calandrinia acaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.	22	1	.	1	1	1	1	.	1	1	1	80
Lupinus ananeanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	10
Baccharido caespitosae-Azorelletum diapensioidis																																																				
Azorella diapensioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	6	8	4	.	4	.	6	.	6	70
Calamagrostis curvula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2	1	2	.	1	1	.	60
Sisyrinchium brevipes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	1	.	.	.	.	40
Baccharis caespitosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	5	4	3	3	.	60
Senecio humillimus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	2	2	40
Sisyrinchium jamesonii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	20
Oxalis eriolepis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	20
Pycnophyllum molle	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	4	3	.	.	.	.	.	30
Aa rosei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	10
Crassuletea connatae																																																				
Muhlenbergia peruviana	1	1	1	1	1	1	2	2	2	2	1	2	1	1	1	1	1	2	1	2	100	1	1	1	1	1	1	1	1	1	100	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	1	.	1	1	1	80
Tagetes multiflora	1	1	1	1	1	.	2	2	2	2	2	2	1	.	2	2	.	2	3	1	85	1	1	1	.	1	.	1	.	1	67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crassula connata	1	1	1	1	.	.	.	.	.	.	.	.	1	1	.	1	.	.	.	.	35	1	1	1	1	1	1	1	1	1	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mancoa hispida	.	.	.	.	.	.	.	.	.	1	1	.	1	.	.	1	1	.	.	.	25	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	1	33	.	.	.	.	.	.	1	.	1	.	20
Chondrosum simplex	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	1	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Argyrochosmetea niveae																																																				
Luzula racemosa	.	.	.	.	.	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	.	.	30
Bomarea dulcis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	30
Paronychia ubinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	20
Asplenium peruvianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	20
Valeriana nivalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	1	.	.	40
Gnaphalium polium	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salpichroa glandulosa	.	.	.	.	.	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	30
Argyrochosma nivea	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	1	2	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia muschleri	.	.	.	.	.	.	.	.	.	1	1	.	.	1	1	.	.	1	1	1	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Peperomia scutellaefolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	44	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	20
Echinopsio-Proustietea																																																				
Adesmia miraflorensis	.	.	.	.	.	.	.	.	.	2	.	2	.	.	.	.	.	.	1	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

# Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	PC	21	22	23	24	25	26	27	28	29	PC	30	31	32	33	34	35	36	37	38	PC	39	40	41	42	43	44	45	46	47	48	PC
Soncho-Bidentetea pilosi																																																				
Trifolium amabile	.	.	.	.	.	.	.	4	.	.	.	.	.	3	4	.	.	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Companions																																																				
Belloa piptolepis	.	.	.	.	.	1	1	2	2	2	.	1	1	1	2	2	2	2	.	1	65	3	2	2	.	1	1	1	.	1	78	1	2	.	1	1	.	1	.	1	67	1	1	1	.	1	1	.	.	.	.	50
Stipa ichu	4	5	4	5	5	4	5	4	4	5	5	4	4	5	4	4	5	4	4	4	100	4	4	4	4	4	4	4	4	4	100	4	6	6	5	5	5	6	5	5	100	4	3	4	3	4	3	4	4	4	4	100
Galium corymbosum	1	1	1	1	1	1	2	1	1	1	1	1	1	2	.	1	1	1	1	1	95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium streptochaetum	1	2	2	2	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	20
Nassella inconspicua	2	4	3	2	2	3	2	2	1	.	.	1	.	2	2	.	.	1	2	.	70	1	2	1	1	3	2	2	2	3	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bartsia crenoloba	1	1	1	1	.	1	2	1	1	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	1	1	.	.	40
Hypochaeris meyeniana	1	2	2	.	.	.	2	2	.	3	.	2	.	.	2	.	.	2	.	.	45	2	2	2	2	1	1	2	1	2	100	.	.	.	.	.	.	.	1	.	11	.	1	1	1	.	1	1	.	1	1	70
Gamochaeta purpurea	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	2	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	20
Bowlesia lobata	1	1	.	1	1	1	1	2	2	2	2	.	1	2	1	1	1	1	1	1	90	.	2	.	2	1	.	1	.	1	56	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	20
Paronychia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	1	.	40
Cardionema ramosissimum	.	.	.	.	.	2	1	2	2	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	1	40
Oxalis megalorrhiza	.	.	.	.	.	1	1	2	1	2	1	2	2	1	.	.	1	2	2	2	65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Laennecia artemisioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	2	3	1	1	1	2	1	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	20
Microsteris gracilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	2	100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Quinchamalium procumbens	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium subspicatum	.	.	.	.	.	.	1	2	1	.	.	1	.	.	.	.	.	1	2	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	20
Gilia laciniata	.	.	.	.	.	1	1	2	2	2	1	1	1	1	2	2	2	2	.	1	70	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bidens andicola	.	.	.	.	.	.	.	.	.	2	3	1	1	2	.	3	3	1	2	2	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perezia pungens	.	.	.	.	.	2	.	2	.	2	3	1	1	2	.	1	1	1	2	2	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	10
Bartsia peruviana	.	.	.	.	.	1	1	2	2	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyperus seslerioides	1	1	1	.	1	2	2	1	1	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Facelis plumosa	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Achyrocline ramosissima	.	.	.	.	.	.	1	2	1	.	.	.	.	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium americanum	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	1	2	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Woodsia montevidensis	.	1	1	.	1	.	.	.	.	1	.	.	1	.	.	.	.	.	.	1	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	20
Cheilanthes pruinata	.	.	.	.	.	2	1	2	2	1	1	.	2	.	2	.	2	3	3	2	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bromus catharticus	.	.	.	.	.	.	.	.	.	2	2	1	1	2	2	.	2	.	1	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cystopteris fragilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	.	30
Vicia andicola	1	2	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis nigricans	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalus micranthellus	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia fasciculata	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	1	2	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Geranium core-core	1	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Descurainia depressa	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	11	.	.	.	.	.	.	.	.	.	.	.
Galinsoga mandonii	.	.	.	.	.	.	.	.	.	1	2	.	1	2	.	1	1	1	2	1	45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria digyna	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	1	1	1	1	1	.	80
Brayopsis calycina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	1	.	.	1	.	50
Senecio candollei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	30
Nototriche anthemidifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	20
Pycnophyllum glomeratum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	10
Junellia minima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2	.	.	.	.	.	.	.	20
Nototriche pedicularifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	10
Oreomyrrhis andicola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	10
Perezia pinnatifida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	10

Sites: 1–5 Tolapampa, Ichuña district; 6–9 Yanahuara, Ichuña district; 10–20 Italpallune, Ichuña district; 21–30 Pirhuani Chico al Rancho, Tassa locality, Ubinas district; 31–39 Yanapuquio, Yanahuara locality, Ichuña district; 40–48 Coalaque, Coalaque locality, Ubinas district

Appendix 6. List of the outlier syntaxa of the Farthest Neighbor Clustering.

- *Polyachyro sphaerocephali-Puyetum densiflorae (Galán de Mera et al. 2009)*
- *Belloo piptolepis-Dissanthelietum calycini, dissanthelietosum calycini, azorelletosum diapensioidis (Galán de Mera et al. 2003)*
- *Nototricho obcuneatae-Xenophylletum poposi, xenophylletosum poposi, valerianetosum nivalis (Galán de Mera et al. 2003)*
- *Chersodomo diclinae-Valerianetum nivalis (Galán de Mera et al. 2003)*
- *Aristeguietio discoloris-Baccharidetum latifoliae, baccharidetosum latifoliae, proustietosum berberidifoliae, polylepidetosum racemosae, Dunalia-Baccharis BC, Cantua buxifolia DC, Stipa-Nassella BC. (Galán de Mera et al. 2004)*
- *Oxalido petrophilae-Cheilanthetum pruinatae (Galán de Mera et al. 2012b)*
- *Cheilanthetum arequipensis (Galan de Mera et al. 2012)*
- *Asplenio triphylli-Melpomenetum moniliformis (Galán de Mera et al. 2014)*
- *Community of Senecio algens (Galán de Mera et al. 2014)*
- *Senecioni culcitioidis-Valerianetum nivalis saxifragetosum magellanicae (Galán de Mera et al. 2014)*
- *Senecioni culcitioidis-Valeranietum nivalis, geographical race with Draba cryptantha (Galán de Mera et al. 2014)*
- *Woodsio montevidensis-Saxifragetum magellanicae (Bolivia: Tunari, Navarro & Maldonado 2002: 268)*
- *Senecioni culcitioidis-Valerianetum nivalis, geographical race with Draba brackenridgei (Galán de Mera et al. 2014)*
- *Senecioni culcitioidis-Valerianetum nivalis, geographical race with Draba cuzcoensis (Galán de Mera et al. 2014)*
- *Senecioni culcitioidis-Valerianetum nivalis mniodetosum andinae (Galán de Mera et al. 2014)*
- *Senecioni culcitioidis-Valerianetum nivalis saxifragetosum magellanicae (Seibert & Menhofer 199)*
- *Valeriano thalictroidis-Saxifragetum magellanicae (Gutte 1986)*
- *Community of Senecio bolivarianus (Galán de Mera et al. 2014)*
- *Race with Liabum bullatum, Calamagrostietea vicunarum (Gutte 1985)*
- *Subass. Tephrocactus floccosus, race with Liabum bullatum (Gutte 1985)*
- *Subass. Hypochaeris eriolaena, race with Liabum bullatum (Gutte 1985)*
- *Race of Poa gymnantha; Calamagrostietea vicunarum (Gutte 1985)*
- *Paspalo tuberosi-Piptochaetium juninensis (Gutte 1985)*
- *Festuco dolichophyllae-Calamagrostietum antonianae (Gutte 1985)*
- *Calamagrostio amoenae-Poetum gymnanthae (Gutte 1985)*
- *Baccharis caespitosa-Parastrephia lepidophylla (Gutte 1985)*
- *Orthosantho ocisanpungae-Puyetum raimondii (Gutte 1985)*
- *Notholaenetea niveae, Differentials with Puya ferruginea, Asplenium fragile, Saxifraga magellanica groups (Gutte 1986)*
- *Senecioni arnaldii-Exhalimolobetum weddellii (Echinopsio-Proustietea) Montesinos et al. 2012*
- *Mostacillastro gracile-Chuquiragetum rotundifoliae (Montesinos et al. 2012)*
- *Anredero diffusae-Diplostephietum meyenii (Montesinos et al. 2012)*
- *Community of Opuntia rosea & Helogyne ferreyrae (Montesinos et al. 2012)*

- *Community of Ophryosporus heptanthus & Escallonia myrtilloides (Montesinos et al. 2012)*
- *Mulino crassifolii-Deyeuxietum crispae (Luebert & Gajardo 2000)*
- *Senecioni zoellneri-Azorelletum compactae (Luebert & Gajardo 2005)*
- *Baccharidetum pentlandii (Seibert & Menhofer 1991)*
- *Saturejetum bolivianae (Seibert & Menhofer 1991)*
- *Mutisietum hirsutae (Seibert & Menhofer 1991)*
- *Kaunietum longipetiolatae (Seibert & Menhofer 1991)*
- *Tagetes pusilla - Succession, Satureion (Seibert & Menhofer 1991)*
- *Festuca dolichophylla grassland steppe (Seibert & Menhofer 1991)*
- *Race of Aciachne (Seibert & Menhofer 1991)*
- *Tillandsia-Felsflur (Seibert & Menhofer 1991)*
- *Senecio adenophylloides-Blockschuttflur (Seibert & Menhofer 1991)*

CHAPTER 5

The Superpuna vegetation of Moquegua, South Peru: Chasmophytes, grasslands and cushion communities

Montesinos, D.B., Cleef, A.M. & Sýkora, K.V.

Abstract

An overview is presented of the syntaxonomy and synecology of superpuna vegetation in 19 localities at an altitude of 4450–4800 m in northern Moquegua (South Peru). The study area has a pluviseasonal climate with summer rainfall. Using TWINSPAN, DCA and a dendrogram method, 153 phytosociological relevés were analyzed. For each community, the syntaxonomy, floristic diversity and relation with environmental variables are described. Four main highland vegetation types were distinguished: 1. slope and scree chasmophyte vegetation composed of shrubs, cushions, ground rosettes and grasses, 2. grasslands (grazed and ungrazed) characterized by great species richness in shrubs, cushions, ground rosettes, grasses and herbs, 3. vegetation of plateaus with cushions, shrubs, ground rosettes, herbs and grasses and 4. nitrophytic vegetation with high cover and low species richness.

Within the vegetation of the orotropical and criorotropical bioclimatic belts four phytosociological classes can be distinguished: *Argyrochosmetea niveae* (chasmophytic vegetation), *Calamagrostietea vicunarum* (grasslands with cushions), *Dielsiochloetea floribundae* (highland slopes and plateaus) and a nitrophitic community. One new association from rock and scree slopes was distinguished within the *Saxifragion magellanicae* (*Argyrochosmetea niveae*). Within the *Calamagrostion minimae*, which comprises grasslands with cushions and mat-forming plants, one new association with two subassociations could be distinguished. Within the grassland and cushion communities of the *Azorello-Festucion* (*Calamagrostietea vicunarum*), three new associations were described, comprising nine subassociations. In the *Anthochloo-Dielsiochloetalia* one new and one previously described association and one community are distinguished. In addition, the nitrophytic community of *Tarasa nototrichoides* and *Urtica flabellata* is distinguished.

In total the vegetation comprised 172 vascular species belonging to 32 families. The puna vegetation of Moquegua hosts some rare, endangered and/or protected plant species in Peru. The vulnerability of the flora and vegetation in the mountains of Moquegua is briefly discussed.

Keywords: Andes, *Argyrochosmetea niveae, Calamagrostietea vicunarum, Anthochloo-Dielsiochloetea, Urticetea flabellatae*, phytosociology, syntaxonomy.

Introduction

From north to south, the South American Andes mountain chain is 9000 km long (Salaverry Llosa 2006). In the traditional vegetation classification of Bolivia, the term puna is used to identify the vegetation of the high plateaus of the Central Andes (Beck & García 1991, García & Beck 2006). Cabrera (1968) defined the puna as a flat area termed Altiplano (Kuentz et al. 2007). Hansen et al. (1984), Thompson et al. (1995), Reese & Liu (2002, 2005), Paduano et al. (2003), Weng et al. (2006) and Kuentz et al. (2007) use the term superpuna to refer to the highest parts of the puna with subnival traces. The few studies known from South Peru relate to the composition and structure of the highland vegetation (Kuentz et al. 2007; Galán de Mera et al. 2003, 2011b, 2014; Montesinos et al. 2012; Montesinos-Tubée et al. 2015a,b), Bolivia (Seibert 1991, 1992, 1993), Chile and Argentina (Cabido & Acosta 1985; Luebert & Gajardo 2000, 2005; Mendez 2014).

Subnival vegetation structure in the Peruvian Andes is influenced by the presence of glaciers. According to Silverio (2003) and Salaverry Llosa (2006), glaciers are present in four regions: the snow peaks of the Cordillera Blanca (Central Peru), Cusco, Puno and Arequipa (South Peru). There may have been glaciers in the region during the Pleistocene and Holocene, and deglaciation in the central Andes has important implications for understanding the regional hydrology and history of highland lakes (Mark et al. 2002). Ribstein et al. (1995) indicate how glacial meltwater could provide a significant buffer to the runoff during the annual tropical dry season, even during dry years.

In this research we define the superpuna as the zone between 4450 m and 4800 m (snowline) which is characterized by average annual temperatures ranging from 6°C at 4500 m to 0°C at 4800 m. Mean annual precipitation is low: between 400 and 600 mm per year (Servicio Nacional de Meteorología e Hidrología del Perú 2013). The tropical Andes is one of the leading biodiversity hotspots worldwide (Myers et al. 2000) and its biome the dry puna is one of the largest pastoral ecosystems, with a unique assemblage of shrubs, tussock grasses, cushions, and mat-forming species (Smith 1994). Cushion plants are abundant in the superpuna and are known to enhance diversity by nursing other species (Catorci et al. 2014, Anthelme et al. 2014, Montesinos 2015a), although some cushions are also known to be non-facilitators (de Bello et al. 2011). In the north of Moquegua (South Peru), the superpuna vegetation is characterized by dwarf and erect shrubs, tussock grasses, annual herbs, ground rosettes, cushions, mats and annual grasses. Most of the Peruvian puna grassland is grazed by livestock (predominantly llamas and alpacas) (Wilcox et al. 1986).

Several authors have studied the vegetation and plant communities of the superpuna of the Central Andes: Galán de Mera et al. (200a2, 2003, 2011b, 2014), Gutte (1985, 1986, 1987), Luebert & Gajardo (2000, 2005), Navarro (1993), Navarro & Maldonado (2002), Rivas-Martínez & Tovar (1982), Ruthsatz (1977), Seibert & Menhofer (1991, 1992, 1993). However, Montesinos et al. (2012) presented the first research on the ecology and structure of the prepuna and puna vegetation found at an altitude between 3470 and 4500 m in the high Andes of North Moquegua. The present contribution is an extension of the study by Montesinos et al. (2012) and Montesinos-Tubée et al. (2015b).

Notwithstanding the previous investigations, more insight into the relation between the plant communities in the superpuna, the floristic composition, environmental variables and anthropic activities is still needed. Thus, the aim of this article is to: (a) present a syntaxonomic characterization of puna vegetation in South Peru, based on full and synoptic tables, (b) determine the distribution of chasmophytic, grassland and plateau vegetations in Moquegua (South Peru), (c) account for their rare and local occurrence and floristic diversity, and (d) evaluate the importance of superpuna rocky slopes, grasslands and cushion communities as habitats for specific vegetation types, and for some endemic plant species in Moquegua (South Peru).

It is unknown for the Moquegua study area how environmental factors such as altitude, slope aspect and angle, cover of rocks and stones, soil properties and the disturbance caused by grazing and fire are affecting the diversity and species composition of the superpuna vegetation. The relation between plant communities and these factors is described here.

The present contribution is an extension of the study by Montesinos et al. (2012) and Montesinos-Tubée et al. (2015b) that described the prepuna and puna vegetation found at an altitude between 3470 and 4500 m in the Moquegua department. The study described here extends the previous observations and represents an altitudinal range of 4450–4800 m.

Study area

The research was conducted in an area of approximately 720 km² in the districts of Ichuña, Ubinas and Yunga, in the General Sánchez Cerro province and the district of Carumas in the Mariscal Nieto province, in the north of the department of Moquegua, South Peru, located at 70°54'02", 70°32'32" W and 16°06'11", 16°15'31" S (Fig. 1, Table 1) at an altitude between 4450 and 4800 m. Average annual precipitation at the Ichuña meteorological station (at 3790 m) is 460 mm, the mean minimum temperature is 3.7 °C and the mean maximum is 19.4 °C (Servicio Nacional de Meteorología e Hidrología del Perú 2013). Precipitation is markedly seasonal, with over 80% of the annual rainfall (600–800 mm) falling between December and April and significant interannual variability (Holmgren et al. 2001, Kuentz et al. 2007). Soil moisture ranges from 0 in the dry season to below 10% in the rainy season (Montenegro et al. 2010). No glaciers have been observed on the highland mountains of North Moquegua. Nevertheless, after heavy rainfall, snow accumulates temporarily above 4700 m altitude. On the summits of the Ubinas volcano (5672 m), snow can be permanent during the rainy season (May-November) and occasionally during the dry season (December-April).

The study area is located in the high altitude sectors of the northwest Andes. Here the geology is volcanic and sedimentary with intercalations of conglomerates and sand; ravines and crevices have infill of sandy silt and calcareous sediment (EIAS-PEC 2009). The fieldwork area comprises the high plateaus and rocky slopes of the two mountain chains of volcanic origin that form the watersheds of the upper Tambo, Paltuture and Ichuña rivers and their tributaries.
Montesinos et al. (2012) presented the vegetation zonation of the upper Tambo River in the Moquegua region and distinguished the orotropical bioclimate occurring between 4450 and 4650 m and characterized by chasmophytic plant communities and grasslands with cushions which occur above 4500 m in the studied regions of Moquegua. The criorotropical zone was identified at altitudes above 4700 m where cushion communities are also present.

Methods

Phytosociology, classification and data collection

The relevés were selected according to the principle of homogeneity as defined by the Zurich-Montpellier method (Braun-Blanquet 1979). Fieldwork was conducted during the months of February, March, April and September in five years: 2009, 2011–2014.

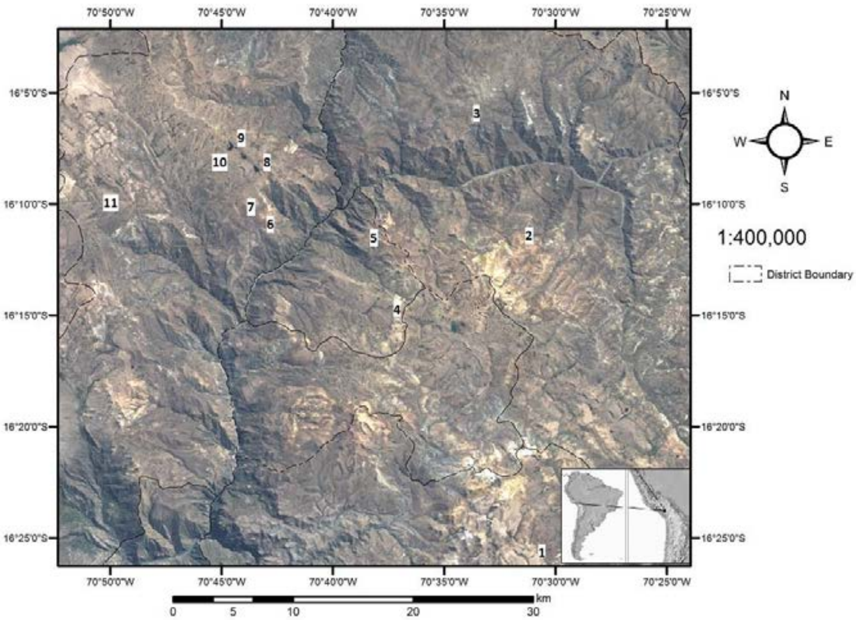

Figure 1. Location of the upper reaches of the Tambo and Ichuña rivers in the Andes of Moquegua, Peru. The black lines indicate the district boundaries. The numbers show the locations of the study sites as listed in table 1. Image source: Landsat 7 Enhanced Thematic. Mapper (ETM+) Acquisition date = 10 May, 2001. Glovis Visualization Portal (http://www.glovis.usgs.gov), a part of the Earth Resources and Science Center (EROS) of the USGS.

Table 1. Overview of parameters for each research site (1–11) in the superpuna of the Andes of Moquegua, Peru. #rel = number of relevés at the site in question, year = year(s) in which fieldwork was done, Elevation = the altitudinal range within which the relevés were made, Slope (°) = minimal and maximal slope angle, Aspect. = orientation, and vegetation = general description of the vegetation structure.

	Sites	Locality	District	# rel.	Year	Elevation (m)	Slope (°)	Aspect	Environment
1	Janchata slopes	Nevados	Carumas	5	2015	4700-4710	5-10	SE	Scree plateaus
2	Cerro Santo Tomas, C. Huarmaca, Puqa Saya	Yanahuara	Ichuña	15	2009, 2012	4530-4665	0-60	N, NW, S, SE	Chasmophyte, scree slopes with copper, steppe grasslands with cushions, rocky slopes, open plateaus, manure communities
3	Coriri, Jatun Puqio, Qhaqhaskinkri	Ichuña	Ichuña	9	2009	4460-4540	3-43	NW, S, SE, E, W	Steppe grasslands with cushions, grazed grasslands
4	Choco-Choco environs	Yunga	Yunga	10	2012	4660-4760	2-35	N, W	Grasslands with cushions, scree slopes, open plateaus with cushions
5	Sura, Perusa-Chaquisura, Siliaca, Yanasaya	Yunga	Yunga	28	2011, 2012	4510-4800	10-50	NW, N, SSW, SW, W	Chasmophyte, rocky slopes, steppe grasslands with cushions, grasslands, scree, open plateaus with cushions
6	Rancho-Pirhuani; Laguna Jallpacocha	Tassa / Pachamay o	Ubinas	18	2014	4450-4565	5-45	NE, SE, E	Steppe grasslands with cushions, grazed grasslands, rocky slopes, scree slopes
7	Pirhuani	Tassa	Ubinas	18	2011	4470-4660	0-17	NNW, SSE, W	Steppe cushion communities
8	Cochapata lake environs	Tassa	Ubinas	10	2013	4680-4700	4-5	SE	Steppe grasslands with cushions
9	Pacosani, Yaretaq, Larsepesca	Coalaque	Ubinas	10	2009	4615-4690	5-47	N, NE, S, SW	Steppe grasslands with cushions, rock slopes
10	Janaqpampa, Gasawasi, Witopata	Querala	Ubinas	10	2011	4500-4640	4-15	S, E, W	Steppe grasslands with cushions, open plateaus
11	Condor Sallana	Matazo	Ubinas	20	2013, 2014	4460-4590	0-25	N, S	Grazed grasslands with cushions, manure communities, rocky slopes

A total of 153 relevés was made in 11 sites within an altitudinal range of 4450–4800 m. The area covered by the relevé was 25 m² for grasslands and cushion communities and 1m², 16m², or 25 m² for chasmophyte and nitrophytic communities (plot size depended on accessibility of sites and homogeneity of the vegetation). For each relevé, the presence of species was noted and its percentage actual cover was estimated (Knapp 1984; Mueller-Dombois & Ellenberg 1974). For computer calculations the percentage values were transformed into a nine-point ordinal cover/abundance scale (Westhoff & Van der Maarel 1973). The scales used were: 1% = 1; 2% = 2; 3% = 3; 4–7% = 4; 8–20% = 5; 21–37 = 6; 38–68% = 7; 69–88% = 8 and 89–100% = 9. The presence of bryophytes and lichens was noted, but the species were not identified. The character and differential species in the description of the communities are mentioned in order of their diagnostic value.

New syntaxa were described following the International Code of Phytosociological Nomenclature (Weber et al. 2000) and new syntaxonomic units were defined after reviewing Galán de Mera (2005) and Galán de Mera et al. (2011b, 2014). The relevés were classified by means of TWINSPAN (Hill 1979) and 15 groups were distinguished (including subassociations); syntaxonomic vegetation tables were constructed and a dendrogram (PC-ORD, Sørensen, Bray-Curtis Distance Measure, Group Average Method) (McCune & Mefford 1999) was made to show the hierarchical similarity structure of the syntaxa described and for their comparison with related communities published in literature. For the dendrogram analysis the species were weighted from 1 to 5 according to their 5-scale presence class in each community, for both our communities and those from the references. In total, 27 communities were compared, including those communities distinguished by Rivas-Martínez & Tovar (1982), Gutte (1987), Seibert & Menhofer (1992), Navarro (1993), Navarro & Maldonado (2002) and Galán de Mera et al. (2003, 2011b, 2014). After excluding ruderals and introduced species, we obtained a total of 299 species (appendix 1) for the analysis.

Detrended Correspondence Analysis (DCA; CANOCO 4.5, Ter Braak & Šmilauer, 2002) was used to study the relation between species composition and environmental variables. As after the first DCA with all 153 samples the relevés clearly fell into two very dissimilar groups, subsequently two separate analysis were performed: one with 112 samples and 153 species (figure 9) and the second with 41 samples and 56 species (figure 10). All species were used based on the data for our communities (1–9, Appendix 1). In the synoptic table (Appendix 1) species constancies are given in percentage values. Full tables are presented in appendices 2 to 10.

We ensured that no sample plots traversed ravines, clefts or streams. In chasmophytic environments, relevés were selected on pure rock stands including soil pockets and crevices in which contact with grassland vegetation was avoided. For each relevé we collected data on altitude (meters above sea level = m.a.s.l.), slope gradient (degrees) and slope orientation (compass), cover of rocks and stones (percentage). Within each relevé, five subsamples were taken from the upper 10 cm of the soil and combined into one bulked sample for pH analysis in the laboratory (only for the relevés done in 2009). The presence of manure was determined by the amount of dung found in each relevé and classed as 0: absence; I: 1–30%; II: 31–70%; III: >71% (dung cover). Grazing intensity was determined by the percentage of tussock grasses showing signs of grazing at the moment of field analysis, and was later converted into I-III values.

The Farthest Neighbor Clustering was done on the basis of communities 1–27 and 299 species (Table 3) which included species and community types found by Navarro (1993), Luebert & Gajardo (2005) and Galán de Mera et al. (2003, 2009, 2011b). The first cluster analysis revealed an outgroup (45 communities by Gutte 1985, 1986; Seibert & Menhofer 1991, 1992; Luebert & Gajardo 2000, 2005; Galán de Mera et al. 2003, 2004, 2009, 2012b, 2014; Navarro & Maldonado 2002 and Montesinos et al. 2012) which was removed prior to the second run. The environmental variables rocks, stones, slope degree and the vegetation cover were presented as box-and-whisker charts and a distribution chart for altitude.

Floristics

The plant species were identified directly in the field; unidentified species were collected and later deposited in various herbaria (USM, HUSA, MOL, CPUN, HUPCH, CUZ, HSP, MO, L; for codes see Index Herbariorum, http://ciweb.nybg.org/science2/IndexHerbariorum.asp). Information on the taxonomy and species distribution was obtained from the literature. The nomenclature of the taxa is in accordance with Brako

& Zarucchi (1993), the electronic versions of Tropicos (2014), IPNI (2014) and The Plant List (2010). Information on the taxonomy and species distribution was obtained from the following: Weberbauer (1945), Al-Shehbaz (1990), Brako & Zarucchi (1993), Funk (1997), Arakaki & Cano (2003), Franco et al. (2004), Linares Perea (2005), Zuloaga et al. (2008), Talavera et al. (2010), Montesinos-Tubée (2011a, 2012a, 2013b, 2014b, 2015b), Britto & Arana (2014), Freire et al. (2015), Montesinos-Tubée & Kool (2015).

Results and Discussion

Syntaxonomic overview

Class: *Argyrochosmetea niveae* Gutte 1986
Order: *Saxifragetalia magellanicae* Galán de Mera & Cáceres 2002
Alliance: *Saxifragion magellanicae* Galán de Mera & Cáceres 2002
1. *Saxifrago magellanicae-Leucherietum daucifoliae* ass. nov.

Class: *Calamagrostietea vicunarum* Rivas-Martínez & Tovar 1982
Order: *Parastrephietalia quadrangularis* Navarro 1993
Alliance: *Calamagrostion minimae* Rivas-Martínez & Tovar 1982
2. *Astragalo minimi-Azorelletum diapensioidis* ass. nov.
2.1 *wernerietosum melanandrae* subass. nov.
2.2 *aciachnetosum pulvinatae* subass. nov.
Alliance: *Azorello compactae-Festucion orthophyllae* Galán de Mera, Cáceres & González 2003
3. *Astragalo pusillii-Parastrephietum quadrangularis* ass. nov.
3.1 *sisyrinchietosum trinervis* subass. nov.
3.2 *baccharidetosum tricuneatae* subass. nov.
3.3 *astragaletosum pusillii* subass. nov.
4. *Senecioni moqueguensis-Pycnophylletum molle* ass. nov.
4.1 *mniodetosum pulvinatae* subass. nov.
4.2 *senecionetosum tassaensis* subass. nov.
4.3 *gentianelletosum primuloides* subass. nov.
4.4 *arenarietosum acaulis* subass. nov.
5. *Calamagrostio trichophyllae-Azorelletum compactae* ass. nov.
5.1 *mniodetosum pickeringii* subass. nov.
5.2 *drabetosum soratensis* subass. nov.

Class: *Anthochloo lepidulae-Dielsiochloetea floribundae* Rivas-Martínez & Tovar 1982
Order: *Anthochloo lepidulae-Dielsiochloetalia floribundae* Rivas-Martínez & Tovar 1982
Alliance: *Nototrichion obcuneatae* Galán de Mera, Cáceres & Gonzáles 2003
Associations and subassociations:

6. *Nototricho obcuneatae-Xenophylletum poposi* Galán de Mera et al. 2003
6.1 *nototrichietosum erinaceae* subass. nov.
6.2 *senecionetosum trifurcifolii* subass. nov.
7. *Poo aequiglumae-Xenophylletum dactylophyllum* ass. nov.
8. Community of *Senecio algens.*

Nitrophytic vegetation
Class, order and alliance: Still to be defined by further research.
9. Community of *Tarasa nototrichoides* and *Urtica flabellata.*

Vegetation description (appendix 1)
Class: ***Argyrochosmetea niveae*** Gutte 1986
Gutte (1986) described the class *Argyrochosmetea niveae* as occurring at an altitude of 2500–3500 m in Junín (Central Peru), with *Argyrochosma nivea,* a species characteristic of rock crevices. Galán de Mera et al. (2003) confirmed the presence of this species in the south of Peru, and we refer to the Argyrochosmetea niveae based on the occurrence of the superpuna alliance Saxifragion magellanicae (Galán de Mera et al. 2002a) where *Saxifraga magellanica* represents the new association *Saxifrago magellanicae-Leucherietum daucifoliae*.

Order: ***Saxifragetalia magellanicae*** Galán de Mera & Cáceres 2002

Table 3. Table with the type relevés of associations and subassociations described as new (including one community and a provisional association). Community # indicated for each association and subassociation; Relevé# for the type relevé or representative relevé. Altitude (meters above sea level). Inclination (degrees). Orientation. Total number of species (# SPP). VEGC % for vegetation cover percentage in that single relevé. Rocks and stones in percentage cover. Grazing and manure (expressed as I: 1–30%; II: 31–70%; III: >71%).

Community #	1	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	4.4	5.1	5.2	6.1	6.2	7	8	9
Relevé #	2	6	20	3	8	20	7	17	33	41	14	20	6	14	2	2	8
ALTITUDE	4580	4585	4470	4450	4510	4500	4670	4610	4680	4590	4800	4590	4650	4710	4790	4745	4460
INCLINATION	25	5	5	5	20	45	10	5	5	10	10	25	5	10	15	45	0
ORIENTATION	S	N	W	NE	N	NW	SW	W	SE	N	W	S	SSE	SE	SSW	NW	-
# SPP	8	18	22	8	15	22	18	12	6	20	16	22	8	8	14	6	5
VEGC %	20	55	45	20	35	60	50	30	35	35	40	45	30	15	15	5	80
ROCKS %	5	5	10	40	40	10	0	20	10	5	20	10	0	5	8	8	0
STONES %	55	5	20	10	10	30	35	35	30	30	40	24	30	90	34	90	0
GRAZING (I-III)	0	0	1	0	1	1	1	0	0	0	0	0	1	0	0	1	3
Argyrochosmetea niveae																	
Saxifragetalia magellanicae, Saxifragion magellanicae																	
Saxifraga magellanica	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifrago magellanicae-Leucherietum daucifoliae																	
Leucheria daucifolia	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Weberbauera sp. (#3842)	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostietea vicunarum																	
Calamagrostis vicunarum	.	.	1	1	.	.	.	2	.	1	.	.	.	.	.	.	.

Community #	1	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	4.4	5.1	5.2	6.1	6.2	7	8	9
Parastrephietalia quadrangularis																	
Parastrephia quadrangularis	.	.	4	2	1	4	.	.	.	.	.	.	.	.	.	.	.
Tetraglochin cristatum	.	4	3	.	.	4	.	2	.	.	.	.	.	.	.	.	.
Descurainia depressa	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Pycnophyllum molle	.	4	4	.	.	.	5	4	3	4	4	.	4	.	.	.	.
Hypochaeris meyeniana	.	.	2	.	1	2	.	.	.	.	.	.	.	.	.	.	.
Ephedra rupestris	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.
Weberbauera spathulifolia	1	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Belloa piptolepis	.	.	.	.	1	1	1	2	.	.	.	.	.	.	.	.	.
Senecio candollei	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.
Senecio humillimus	.	.	.	.	2	.	.	.	.	.	.	2	.	.	.	.	.
Brayopsis monimocalyx	.	1	1	.	.	.	.	.	.	1	1	.	.	.	.	.	.
Chaetanthera stuebelii	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.
Nototriche anthemidifolia	.	1	.	.	.	.	2	1	.	1	1	.	.	.	.	.	.
Draba macleanii	.	2	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Hypochaeris eriolaena	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Plantago sericea var. *lanuginosa*	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Werneria aretioides	.	.	2	.	.	.	.	2	2	.	.	.	.	.	.	.	.
Senecio spinosus	.	3	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Werneria pectinata	.	.	.	.	1	.	1	.	.	2	.	.	.	.	.	.	.
Wahlenbergia peruviana	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Nototriche digitulifolia	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Nototriche pedicularifolia	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lupinus ananeanus	.	.	3	.	.	3	.	.	.	.	.	.	.	.	.	.	.
Cerastium subspicatum	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Conyza deserticola	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gomphrena meyeniana	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostietea minimae																	
Calamagrostis minima	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Werneria nubigena	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalo minimi-Azorelletum diapensioidis																	
Azorella diapensioides	.	2	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalus minimus	.	4	2	.	2	2	1	.	.	.	.	.	.	.	.	.	.
Bougueria nubicola	.	2	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.
Werneria apiculata	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Junellia minima	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
wernerietosum melanandrae																	
Werneria melanandra	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nototriche longirostris	.	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
aciachnetosum pulvinatae																	
Aciachne pulvinada	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Azorello-Festucion																	
Azorella compacta	.	.	.	2	3	4	.	.	3	4	4	4	.	.	.	.	.
Festuca orthophylla	.	.	.	.	.	2	4	.	.	.	.	.	.	.	.	.	.
Baccharis caespitosa	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.
Belloa sp. (#3945)	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.
Bowlesia tropaeolifolia	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Cumulopuntia boliviana subsp. *ignescens*	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.
Senecio evacoides	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.
Stangea wandae	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.
Astragalo pusillii-Parastrephietum quadrangularis																	
Astragalus pusillus	.	.	.	1	1	2	.	.	.	.	.	.	.	.	.	.	.
sisyrinchietosum trinervis																	
Sisyrinchium trinervis	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
baccharidetosum tricuneatae																	
Baccharis tricuneata	.	.	.	.	2	.	.	.	.	.	2	2	.	.	.	.	.
Descurainia sp. (#0940)	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
astragaletosum pusillii																	
Sisyrinchium brevipes	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Senecioni moqueguensis-Pycnophylletum molle																	
Senecio moqueguensis	.	.	.	.	.	.	2	1	2	2	.	.	.	.	.	.	.
Nototriche argentea	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.

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Community #	1	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	4.4	5.1	5.2	6.1	6.2	7	8	9
Perezia coerulescens var. *amplibracteata*	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
mniodetosum pulvinatae																	
Mniodes pulvinata	.	.	.	.	.	.	2	.	.	.	.	2	.	.	.	.	.
Senecio bolivarianus	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
senecionetosum tassaensis																	
Senecio tassaensis	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Xenophyllum weddellii	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.
gentianelletosum primuloides																	
Gentianella primuloides	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Senecio graveolens	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
arenarietosum acaulis																	
Arenaria acaulis	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Nototriche sepaliloba	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Cerastium behmianum	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Nototriche pusilla	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Senecio sykorae	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Poa brevis	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Calamagrostio trichophyllae-Azorelletum compactae																	
Calamagrostis trichophylla	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
Nototriche mandoniana	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Silene mandonii	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Perezia pungens	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
mniodetosum pickeringii																	
Mniodes pickeringii	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.
Senecio sp.2 (#3935)	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.
drabetosum soratensis																	
Draba soratensis	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Bartsia sp. (#3092)	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Poa gilgiana	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Agrostis breviculmis	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Viola granulosa	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Anthochloo-Dielsiochloetea																	
Anthochloa lepidula	1	.	.	.	.	.	1	.	.	.	.	.	1	1	1	1	.
Dielsiochloa floribunda	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Nototrichion obcuneatae																	
Nototriche obcuneata	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.
Senecio rufescens	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.
Senecio sp.3 (#3931)	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.
Dissanthelium calycinum	.	1	.	.	.	1	.	.	.	1	.	.	.	.	1	.	1
Nototriche sp.1 (#3104)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Nototricho obcuneatae-Xenophylletum poposi Galán de Mera et al. 2003																	
Xenophyllum poposum	.	.	.	.	.	.	.	.	.	.	.	.	3	2	.	.	.
Mniodes coarctata	.	.	.	.	.	.	.	.	.	2	.	.	3	2	.	.	.
nototrichietosum erinaceae																	
Nototriche erinacea	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.
senecionetosum trifurcifolii																	
Senecio trifurcifolius	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.
Senecio sp.4 (#4228b)	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Poo aequiglumae-Xenophylletum dactylophyllum																	
Xenophyllum dactylophyllum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.
Nototriche sp.3 (#2447)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Poa aequigluma	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.
Poa spicigera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Community of *Senecio algens*																	
Senecio algens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Senecio sp.5 (#3942)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.
Class ¿?																	
Community of *Tarasa nototrichoides* and *Urtica flabellata*																	
Urtica flabellata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Tarasa nototrichoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2

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Community #	1	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	4.4	5.1	5.2	6.1	6.2	7	8	9
Lachemilla pinnata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Perezia multiflora	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
Solanum acaule	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Crassuletea connatae																	
Muhlenbergia peruviana	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salpichroetalia glandulosae; Argyrochosmetea niveae																	
Valeriana nivalis	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.
Companions																	
Bartsia diffusa	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis curvula	.	.	.	.	.	.	.	.	.	.	1	.	1	.	1	1	.
Cardionema ramosissimum	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Galium corymbosum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Geranium sessiliflorum	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Lepidium meyenii	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Luzula vulcanica	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Mancoa hispida	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Microsteris gracilis	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxalis nubigena	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Parastrephia lucida	.	.	.	.	.	.	3	.	.	2	2	2	.	.	2	.	.
Paronychia andina	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Poa candamoana	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Pycnophyllum glomeratum	.	.	.	.	.	.	.	2	.	.	.	2	.	.	2	.	.
Senecio nutans	.	.	.	.	.	2	.	.	.	.	1	.	.	.	2	.	.
Stangea rhizanta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Stipa ichu	1	.	4	1	3	3	.	.	.	.	.	.	.	.	.	.	.
Trisetum spicatum	.	.	.	.	.	.	.	.	.	.	.	2	.	1	.	.	.

Alliance: ***Saxifragion magellanicae*** Galán de Mera & Cáceres 2002

Physiognomy, composition and distribution: The order and alliance combine the basaltic and andesite soils along the Andes of Peru, from Lima to Tacna regions (Galán de Mera et al. 2014). In our study it combines the vegetation growing on deep soils with fine scree across rock crevices, in the north of Moquegua, South Peru. It grows on the south-facing highlands of the Yanahuara River in Ichuña locality. *Saxifraga magellanica* is a cushion-forming herb with rosette leaves and whitish flowers; its distribution area is from Colombia to NW Argentina (Tropicos 2014).

Syntaxonomy: Diagnostic species is *Saxifraga magellanica.*

Saxifrago magellanicae-Leucherietum daucifoliae ass. nov.

(Typus: Rel. 2, col. 1, Table 2; Table 3, col. 1; Appendix 1, col. 2; Figure 2)

Physiognomy and composition: Association of chasmophyte vegetation, with a variable cover by cushions, herbs and grasses. It consists of 4–20 cm tall cushions and herbs with a cover of 10–20% in combination with tussock grasses and dwarf shrubs (*Ephedra rupestris*) with a cover of 5%. Among the surface layer species with substantial cover are *Leucheria dauciflora, Saxifraga magellanica, Calandrinia acaulis, Weberbauera spathulifolia* and *Microsteris gracilis.* The cushion *Pycnophyllum molle* presence in two relevés facilitates the presence of the rare orange-flowered *Gentianella incurva.* The grass layer is composed of the tussock *Stipa ichu* and the small grass *Anthochloa lepidula.*

Syntaxonomy: The description of this association is based on 5 relevés containing 20 vascular species. Character species are *Leucheria dauciflora, Perezia nivalis, Saxifraga magellanica, Gentianella incurva, Weberbauera* sp. (# 3842) and *Perezia pinnatifida.* Differentials against other classes are *Poa candamoana* and *Stangea rhizanta.*
Ecology and distribution: This Andean chasmophyte community is generally found delimited by grassland communities, plateaus and steep rock formations, at edges of slopes or on hilltops. It is located at altitudes of 4580–4590 m, on south-facing slopes of 5–25°. The soils are mainly formed by unstable scree high in copper minerals, with stone particles and grayish-green mottling in the upper soil horizons. This community can be found on the rocky slopes of the Ichuña River valley, in the north of the Ichuña district.

Class: ***Calamagrostietea vicunarum*** Rivas-Martínez & Tovar 1982
The Calamagrostietea vicunarum grows on clay and loamy clay (rarely on sand) on rocky slopes, plateaus and hills at 4450–4800 m. In the Andean regions of North Moquegua, downslope it is in contact with the grassland vegetation dominated by *Lupinus paruroensis* and the giant bromeliad *Puya raimondii* and upslope with units of the *Anthochloo-Dielsiochloetea*. The diagnostic species of the class is *Calamagrostis vicunarum.*
At the class level, we consider the name *Deyeuxia vicunarum* to be invalid for the new class name *Deyeuxietea vicunarum* Rivas-Martínez & Tovar suggested by Galán de Mera et al. (2014) since this name is not valid according to Tropicos (2013) and The Plant List (2014); according to the latter authorities, *Deyeuxia vicunarum* should be considered to be a synonym for *Calamagrostis vicunarum.* Therefore we suggest that the name Calamagrostietea vicunarum Rivas-Martínez & Tovar should be maintained and not changed.

Parastrephietalia quadrangularis Navarro 1993
This order combines the puna grasslands, the *Parastrephia quadrangularis* and *P. lucida* communities proper of the central and southern Andes occupying the orotropical and criorotropical bioclimatic belts (Navarro 1993). Its area extends from southwest Peru to west of Bolivia, northwest Argentina and northwest Chile.
The following characteristic species have been found in our area: *Belloa piptolepis. Brayopsis monimocalyx, Cerastium subspicatum, Chaetanthera stuebelii, Conyza deserticola, Descurainia depressa, Draba macleanii, Ephedra rupestris, Erigeron rosulatus, Gomphrena meyeniana, Hypochaeris eriolaena, Hypochaeris meyeniana, Lobivia maximiliana, Lupinus ananeanus, Nototriche anthemidifolia, Nototriche digitulifolia, Nototriche pedicularifolia, Oxalis calachaccensis, Parastrephia quadrangularis, Perezia coerulescens, Plantago sericea* var. *lanuginose, Pycnophyllum molle, Senecio candollei, Senecio humillimus, Senecio spinosus, Silene genovevae, Tetraglochin cristatum, Wahlenbergia peruviana, Weberbauera spathulifolia, Werneria aretioides* and *Werneria pectinata.*

Alliance: ***Calamagrostion minimae*** Rivas-Martínez & Tovar 1982
(Table 3, col. 2; Appendix 2)
Physiognomy and composition: Characterized by the presence of cushion plants, dwarf shrubs, tussock grasses, annual grasses and herbs. The high cover of the cushion Azorella diapensioides together with the mat-forming *Astragalus minimus* characterizes the association described for this alliance.
Syntaxonomy: The following species characteristics of the alliance have been found in North Moquegua: *Calamagrostis minima, Calandrinia acaulis, Oreomyrrhis andicola* and *Werneria nubigena*.
Ecology and distribution: The alliance occurs in the grassland puna known as “cesped de puna” formed by small herbs and ground rosettes with long root systems, mostly developing on open and uniform slopes with shallow soils. The alliance is known to occur in the highlands of Peru and Bolivia (Rivas-Martínez & Tovar 1982; Galán de Mera 2005).

Astragalo minimi-Azorelletum diapensioidis ass. nov.
(Typus: Rel. 6, col. 2.1, Table 2; col. 2, Table 3; Appendix 2)
Physiognomy and composition: Grassland vegetation with high density and diversity of dwarf shrubs, cushions, grasses, ground rosettes and annual herbs. Vegetation cover of about 20–80%. The 20–40 (50) cm tall resinous shrubs of *Parastrephia quadrangularis* cover 10% in four relevés only. Cushions attain 15–30% of the total cover and are represented by *Azorella diapensioides* and *Pycnophyllum molle*. *Pycnophyllum glomeratum* attains low cover in two relevés only. The grasses are mostly represented by *Festuca orthophylla,* which reaches high cover in most of the relevés. The ground layer is represented by few species with high cover: *Dissanthelium calycinum, Hypochaeris meyeniana, Brayopsis monimocalyx, Werneria pectinata, Belloa piptolepis, Astragalus minimus, Werneria apiculata, Aciachne pulvinata, Bouguiera nubicola, Oreomyrrhis andicola,* the dwarf shrub *Tetraglochin cristatum,* among others. The absence of *Festuca dolichophylla* and *Baccharis tricuneata* is diagnostic. Ferns are absent. The mat-forming *Astragalus minimus* is dominant and forms dwarf and compact mats that extend to 30–40 cm in diameter; in common with other species of cushion plants, these cushion plants also host other species. This association is characterized by the absence of *Azorella compacta.*
Syntaxonomy: This association is defined on the basis of 24 relevés containing 68 vascular species. Character species are: *Astragalus minimus, Azorella diapensioides, Bougueria nubicola, Nototriche turritela, Werneria apiculata* and *Nototriche longirostris*. Differential species include: *Crassula connata, Gomphrena meyeniana, Oxalis calachaccensis, Cyperus seslerioides* and *Lupinus cuzcensis.*
Ecology and distribution: The association develops between 4460–4670 m altitude, covering extensive plateaus on slopes of about 11° with varied aspect. Soil texture is

composed by fine scree, clay and sandy clay, with few rocks and stones. Vegetation cover attains 57% on average. The association occurs in the highlands of the Ichuña district, near Cachilaya, Coriri, Jatun Puqio and Qhaqhaskinkri and the southern lower slopes of Pirhuani peak (Ubinas district). The association borders the communities formed by *Azorella compacta*, grasslands and chasmophytic units.

The *Astragalo minimi-Azorelletum diapensioidis* (*Calamagrostion minimae* Rivas-Martínez & Tovar 1982) differs greatly from the *Parastrephio lucidae-Festucetum orthophyllae azorelletosum diapensioidis* (Galán de Mera et al. 2003) and *Baccharido caespitosae-Azorelletum diapensioidis* because of the absence of *Festuca dolichophylla, Baccharis caespitosa* and other elements of the puna. We have included this association in the *Calamagrostion minimae* (Rivas-Martínez & Tovar 1982) because of the abundance of cushion plants such as *Azorella diapensioides* and the presence of small grasses such as *Calamagrostis minima*, and the absence of some species characterizing the *Azorello-Festucion*.

wernerietosum melanandrae subass. nov.
(Typus: Rel. 6, col. 2.1, Table 2; col. 2, Table 3; Appendix 2)
Physiognomy and composition: Characterized by the abundance of *Astragalus minimus* together with *Azorella diapensioides, Pycnophyllum molle, Tetraglochin cristatum* and *Werneria melanandra*. Other differences include the absence of several species belonging to the plateaus, which have greater species diversity, probably because more nutrients are available in the soil.
Syntaxonomy: The *wernerietosum melanandrae* is differentiated by *Werneria melanandra, Junellia minima, Cerastium subspicatum, Astragalus peruvianus, Draba macleanii* and *Sisyrinchium brevipes*.
Ecology and distribution: This subassociation develops on plateaus and slopes with a mixture of clayey sand and scree with concentrations of copper minerals, at altitudes ranging from 4580 to 4590 m in the sector of Puqa Saya, in the Ichuña district.

aciachnetosum pulvinatae subass. nov.
(Typus: Rel. 20, col. 2.2, Table 2; col. 2, Table 3; Appendix 2)
Physiognomy and composition: By comparison with the *wernerietosum melanandrae*, the herb layer is more species-rich, herbs and cushions are more abundant; *Azorella diapensioides* is common.
Syntaxonomy: The subassociation is species-rich and many differential species were identified: *Aciachne pulvinata, Anthochloa lepidula, Astragalus uniflorus, Bartsia diffusa, Belloa piptolepis, Belloa schultzii, Cardionema ramosissimum, Conyza deserticola, Crassula connata, Cyperus seslerioides, Descurainia depressa, Lupinus ananeanus, Mancoa hispida, Microsteris gracilis, Nototriche digitulifolia, Nototriche mandoniana, Nototriche pusilla,*

Ourisia muscosa, Oxalis calachaccensis, Poa spicigera, Pycnophyllum glomeratum, Senecio candollei, Spergularia andina, Stipa ichu, Tarasa nototrichoides, Viola hillii, Wahlenbergia peruviana, Weberbauera spathulifolia, Werneria aretioides and *Werneria pectinata*.
Ecology and distribution: The vegetation of this subassociation grows on extensive plateaus covered by clayey sand and with a relatively high cover of stones; rocks are almost absent. The subassociation develops between abundant rocks and stones, at altitudes between 4460 and 4670 m.

Alliance: ***Azorello compactae-Festucion orthophyllae*** Galán de Mera, Cáceres & Gonzáles 2003
Physiognomy and composition: In this paper the alliance is based on 97 relevés containing 140 plant species. The relative high presence and cover of the composite resinous shrub Parastrephia lucida that replaces Parastrephia quadrangularis in the altitudinal gradient characterize the communities described. The cushions *Pycnophyllum molle* and *Azorella compacta* are relatively abundant, together with the relative high cover of the tussock *Festuca orthophylla* which replaces *Festuca dolichophylla* as well as from the higher altitudinal gradient context. *Festuca dolichophylla* (which is a species from the lower altitudinal gradient)
Syntaxonomy: The following species are characteristic of the alliance in North Moquegua:
Azorella compacta, Baccharis caespitosa, Baccharis tricuneata, Bartsia elongata, Belloa sp. (# 3945), *Bowlesia tropaeolifolia, Caiophora rosulata, Cumulopuntia boliviana* subsp. *ignescens, Festuca orthophylla, Senecio evacoides* and *Stangea wandae.*
Ecology and distribution: This alliance dominates extensive areas in the puna and superpuna of North Moquegua, occurring in the Arequipa, Tacna and Puno departments. In our study region, it occurs between 4450–4800 m. It comprises different units of vegetation represented by grasslands with cushions, open plateaus with cushions, vertical cushion formations and scree communities with cushions and dwarf shrubs. The inclination varies from 0 to 90° and the orientation is variable. Grazing intensity varies; some grasslands are heavily grazed while others can be considered to be ungrazed.
The grassland with cushion vegetation of South Peru is grouped into the *Azorello compactae-Festucion orthophyllae* (Galán de Mera & Gonzáles 2003, 2009, 2011b). For North Moquegua we described three associations with nine subassociations belonging to this alliance. The vegetation with the cushion *Azorella compacta* is assigned to this alliance and here described with three new associations. The distribution of *Azorella compacta* can be found in some restricted Andean regions in South Peru (Weberbauer 1945; Ralph 1978; Talavera et al. 2010; Montesinos-Tubée 2011a), Bolivia (Wickens 1995), Argentina (Martínez 1989) and Chile (Teillier 1998; Kleier et al. 2015).
The *Azorello compactae-Festucion orthophyllae* represents the large tracts of superpuna grasslands in South Peru, in the Moquegua region where *Festuca orthophylla, Tetraglochin*

cristatum, Parastrephia quadrangularis and *P. lucida* are common. *Festuca orthophylla* is the tussock grass that dominates the superpuna grasslands of Moquegua in association with the resinous shrub *Parastrephia quadrangularis*, which is replaced by *Parastrephia lucida* at altitudes higher than 4500 m and is well represented in the superpuna. The tussock *Festuca orthophylla* is distributed in our study sites at altitudes between 4450 and 4800 m, becoming more abundant at 4650 m and higher. The tussock grass distribution is in agreement with Navarro & Ferreira (2004), who recorded *Festuca dolichophylla* in the subhumid puna of Bolivia at 3500–4000m and 4500 m and *Festuca orthophylla* at higher altitudes, in the super puna and subnival puna (uppermost part of the superpuna); above 4500 m *Festuca orthophylla* co-occurs with cushion plants such as *Azorella* and *Pycnophyllum.* We found the same co-occurrence in the Andes of North Moquegua and presume that the species also occurs in the high Andes of Arequipa and Tacna.

The new associations and subassociations with *Azorella compacta* described here differ from each other not only in species composition but also in altitude and distribution. The subassociations also differ greatly in slope orientation, rockiness percentage and grazing.

Within the *Azorello compactae-Festucion orthophyllae* we distinguish three different associations with nine subassociations.

Astragalo pusillii-Parastrephietum quadrangularis Ass. Nov.
(Typus: Rel. 20, col. 3.3, Table 2; col. 3, Table 3; Appendix 3)

Physiognomy and composition: The association is characterized by the co-occurrence of the aromatic shrub *Senecio nutans* and the leptophyllous shrub *Parastrephia quadrangularis.* Galán de Mera et al. (2011b) refers to this community as orotropical and dry, situated on volcanic sediments and alluvial materials from the Pleistocene, which form large rocky slopes with soils of variable depth. In terms of composition, this association differs from other similar communities by the permanent presence of *Parastrephia quadrangularis, Azorella compacta* and the tussock *Stipa ichu.* In contrast with other associations, *Gomphrena meyeniana, Senecio evacoides, Pycnophyllum glomeratum, Nototriche mandoniana* and *Werneria aretioides* are absent.

Syntaxonomy: In our study, the *Astragalo pusillii-Parastrephietum quadrangularis* is based on 23 relevés containing 73 plant species. According to our research the following species can be considered to be character species of this association: *Astragalus pusillus, Sisyrinchium brevipes, Sisyrinchium trinervis, Conyza* sp. (# 2601), and with lower frequency *Valeriana aschersoniana, Belloa longifolia, Descurainia* sp. (# 0940) and *Junellia* sp. (# 4019).

In addition, species such as *Perezia multiflora, Galium corymbosum, Loricaria graveolens, Oxalis nubigena, Lobivia maximiliana, Asplenium peruvianum, Adesmia spinosissima, Oxalis debilis* and *Weberbauera peruviana* are considered to be differential against the other alliances.

Ecology and distribution: The *Astragalo pusillii-Parastrephietum quadrangularis* is widespread on the southern slopes of Peru in areas with intense grazing. In our study area it occurs between 4450–4560 m. The community develops on slopes (mean inclination: 22°) with a relatively high cover of rocks (mean: 28%) and stones (20.6%). We distinguished three new subassociations distributed in the Rancho-Pirhuani area and environs of Condor Sallana, near Matazo locality (Ubinas district), Siliaca (Yunga district) and Qhaqhaskinkri in the Ichuña district.

sisyrinchietosum trinervis subass. nov.
(Typus: Rel. 3, col. 3.1, Table 2; col. 3, Table 3; Appendix 3)
Physiognomy and composition: Characterized by the relative abundance of *Sisyrinchium trinervis* together with *Pycnophyllum molle, Paronychia andina* and *Parastrephia quadrangularis.* Annual herbs are relatively abundant but low in cover; like the cushions and shrubs, their cover is between 15 and 20%. The cushion *Azorella compacta* is present in four relevés.
Syntaxonomy: The *sisyrinchietosum trinervis* is differentiated by *Sisyrinchium trinervis, Loricaria graveolens, Cerastium subspicatum, Nototriche digitulifolia* and *Senecio candollei.*
Ecology and distribution: The *sisyrinchietosum trinervis* grows on bare soils on slopes with 5–20° inclination and facing N to NE. Rocks cover between 25–50% and stones between 10–15%. Three out of ten relevés appeared to be intensively grazed. The *sisyrinchietosum trinervis* occurs between 4450–4460 m in the Rancho-Pirhuani area, near Tassa locality in the Ubinas district and it borders the chasmophytic *Loricario graveolensi-Pycnophylletum mollis* (Montesinos-Tubée et al. 2015b) and the *Calamagrostion minimae* (this study, Montesinos-Tubée et al. 2015b) units in the upper series.

baccharidetosum tricuneatae subass. nov.
(Typus: Rel. 8, col. 3.2, Table 2; col. 3, Table 3; Appendix 3)
Physiognomy and composition: Characterized by the abundance of *Baccharis tricuneata* together with *Stipa ichu, Azorella compacta, Parastrephia quadrangularis* and *Belloa piptolepis.* The herb layer is dominated by *Calamagrostis vicunarum, Werneria pectinata, Galium corymbosum* and *Bartsia diffusa*. The cushion *Pycnophyllum molle* occurs in four relevés and *Senecio nutans* is found in five relevés only.
Syntaxonomy: The *baccharidetosum tricuneatae* is mainly differentiated by *Baccharis tricuneata, Werneria pectinata* and *Muhlenbergia peruviana* and by some other species with low cover only, such as *Descurainia* sp. (# 0940), *Junellia* sp. (# 4019) and *Valeriana aschersoniana*.
Ecology and distribution: This subassociation develops on plateaus and slopes with clayey soils; 20–50% of the surface is covered by rocks. Most relevés are intensively grazed and contain manure. The *baccharidetosum tricuneatae* grows between 4500–4560

m. Its vegetation cover is about 45%. It is found in the surroundings of the road between Carmen Chaclaya and Matazo sites in the Ubinas district.

astragaletosum pusillii subass. nov.
(Typus: Rel. 20, col. 3.3, Table 2; col. 3, Table 3; Appendix 3)
Physiognomy and composition: By comparison with the other subassociations of the *Astragalo pusillii-Parastrephietum quadrangularis*, the vegetation cover and species richness are higher. The species composition comprises several companions, probably as an effect of grazing. The shrub *Parastrephia quadrangularis* is abundant and covers 10–15%, the cushion *Azorella compacta* also attains a high cover compared to the other units, and so does the spiny shrub *Tetraglochin cristatum.*
Syntaxonomy: This subassociation is mainly differentiated by *Astragalus pusillus, Wahlenbergia peruviana, Silene genovevae, Nototriche longirostris, Sisyrinchium brevipes* and *Conyza* sp. (# 2601), but also by the low frequency of *Lepidium meyenii, Cardionema ramosissimum, Mancoa hispida* and *Tarasa nototrichoides.*
Ecology and distribution: The *astragaletosum pusillii* occurs between 4500 and 4540 m on stony slopes in the Coriri and Qhaqhaskinkri sites in the Ichuña district. On average, the measured pH was 5.6.

Senecioni moqueguensis-Pycnophylletum molle ass. nov.
(Typus: Rel. 7, col. 4.1, Table 2; col. 4, Table 3; Appendix 4; Figure 4)
Physiognomy and composition: Plateau vegetation with abundant cushion and mat-forming plants. Vegetation cover varies between 30–70%. Bare soil is frequently covered by fine stone particles. Shrubs are less frequent and cover between 4–8% (20–40 cm height); they are mainly represented by *Baccharis tricuneata* and *Parastrephia lucida*.
Syntaxonomy: This association is defined on the basis of 43 relevés with 94 vascular species. Character species are *Senecio moqueguensis, Nototriche argentea, Perezia coerulescens* var. *amplibracteata* and *Senecio* sp.1 (# 4217a). Differentials against other associations include: *Mniodes coarctata, Geranium sessiliflorum, Calandrinia acaulis, Hypochaeris eriolaena* and *Werneria aretioides.*
Ecology and distribution: The vegetation represented by the *Senecioni moqueguensis-Pycnophylletum molle* spreads over areas with partial rock cover (13%) and stones (28%) in the extensive plateaus surrounding bogs and lakes at an altitude of 4500–4830 m in North Moquegua. The slopes (about 11° with varied aspect) for this association are characterized by the abundance of the cushion *Pycnophyllum molle* and, with less presence, *Azorella compacta*. Wild animals were seen in the landscape during fieldwork; dung from domesticated bull (*Bos taurus*), vicuña (*Vicugna vicugna*) and deer (*Hippocamelus antisensis*) was recognized in a few relevés across the sites. The near absence of tussocks suggests there was no grazing: the wild animals tend to graze other species such as small grasses and herbs. The distribution is limited to Gasawasi-Witopata plateaus, the

northern lower slopes of Pirhuani peak, the extensive plateaus surrounding the group of lakes upslope Coalaque and Querala localities, the Matazo locality environs (Ubinas district) and the Choco-Choco lower mountain slopes in Yunga district.

mniodetosum pulvinatae subass. nov.
(Typus: Rel. 7, col. 4.1, Table 2; col. 4, Table 3; Appendix 4)
Physiognomy and composition: By comparison with the other subassociations of the Senecioni moqueguensis-Pycnophylletum molle, the vegetation attains lower cover and lower species richness. Stones (24%) have a higher cover than rocks (9%). The cushion *Pycnophyllum molle, Senecio moqueguensis* (mat-forming), *Mniodes pulvinata* (a rigid cushion with grayish leaves in a rosette and inconspicuous yellow flowers) and *Azorella compacta* are frequent. Tussock grasses are represented by *Festuca orthophylla* in twelve relevés. Shrubs are well represented by *Baccharis tricuneata* and *Parastrephia lucida*.
Syntaxonomy: This subassociation is differentiated by *Mniodes pulvinata, Myrosmodes* sp. (# 2287), *Lupinus* sp. (# 2424) and *Senecio bolivarianus*. *Weberbauera spathulifolia, Hypochaeris eriolaena, Poa candamoana, Perezia coerulescens, Bougueria nubicola* and *Lepidium meyenii* are differential against the other subassociations.
Ecology and distribution: The mniodetosum pulvinatae grows between 4530 and 4700 m, on the extensive plateaus (5–20°) and rocky slopes (20–45°) of the Gasawasi-Witopata site, the northern lower slopes of Pirhuani peak, the extensive plateaus surrounding the group of lakes upslope Coalaque and Querala localities (Ubinas district) and the Choco-Choco lower mountain slopes in Yunga district. Vegetation cover attains 20–70%; soils are a mixture of clayey sand with pH ranging between 4.8 and 6.5.

senecionetosum tassaensis subass. nov.
(Typus: Rel. 17, col. 4.2, Table 2; col. 4, Table 3; Appendix 4)
Physiognomy and composition: Characterized by the low abundance of *Xenophyllum weddellii* and of *Stangea wandae. Pycnophyllum molle, Senecio moqueguensis, Werneria aretioides* and *Belloa piptolepis* attain high cover. Other differences include the absence of shrubs, except for *Tetraglochin cristatum*, which acquires a decumbent habit on the slopes. The cushion *Azorella compacta* is less frequent in the company of *Pycnophyllum molle.* Species richness is relatively high, probably due to the presence of species related to grazing and manure.
Syntaxonomy: The *senecionetosum tassaensis* is mainly differentiated by species such as *Senecio tassaensis, Xenophyllum weddellii, Oritrophium* sp. (# 2194b) and *Werneria heteroloba*.
Ecology and distribution: This subassociation develops on plateaus (5°) and slopes (8–14°) with a mixture of clayey sand, at altitudes between 4510 and 4700 m on the northern plateaus of the Ubinas district.

gentianelletosum primuloides subass. nov.
(Typus: Rel. 33, col. 4.3, Table 2; col. 4, Table 3; Appendix 4)
Physiognomy and composition: This subassociation is characterized by thirty-four species recorded from 7 relevés. *Senecio moqueguensis* has low constancy and cover and occurs in combination with *Pycnophyllum molle, P. glomeratum, Azorella compacta, Festuca orthophylla, Parastrephia lucida* and *Stangea rhizantha.*
Syntaxonomy: The gentianelletosum primuloides is differentiated by species such as *Gentianella primuloides, Senecio graveolens, Xenophyllum digitatum* and *Viola* sp. (# 4217a).
Ecology and distribution: The gentianelletosum primuloides grows between 4590 and 4680 m, on the extensive plateaus (5–10°) of the Yunga district. Vegetation cover attains 35–65%.

arenarietosum acaulis subass. nov.
(Typus: Rel. 41, col. 4.4, Table 2; col. 4, Table 3; Appendix 4)
Physiognomy and composition: Characterized by the abundance of *Senecio moqueguensis* together with *Pycnophyllum molle, Azorella compacta, Parastrephia lucida, Mniodes coarctata* and *Werneria pectinata*.
Syntaxonomy: The arenarietosum acaulis is differentiated by *Arenaria acaulis, Nototriche sepaliloba, Cerastium behmianum, Nototriche pusilla, Senecio sykorae, Poa brevis, Spergularia andina* and *Werneria* sp. (# 3940).
Ecology and distribution: The vegetation of the subassociation grows on rocky soils, on slopes and plateaus at altitudes between 4570–4590 m in the Condor Sallana environs close to Matazo locality (Ubinas district).

Calamagrostio trichophyllae-Azorelletum compactae ass. nov.
(Typus: Rel. 14, col. 5.1, Table 2; col. 5, Table 3; Appendix 5; Figure 5)
Physiognomy and composition: In total, 59 species, including many endemics, were recorded from twenty-two relevés. Shrubs are more frequent than in the preceding communities. The diagnostic cushion *Azorella compacta* can reach up to 50 cm in height with 1.5 m of diameter. Other cushions and mat-forming species are also common (*Pycnophyllum molle, P. glomeratum, Brayopsis monimocalyx, Senecio humillimus, S. evacoides, Erigeron rosulatus*), together with many rosette herbs and grasses. Shrubs are mostly represented by the constant *Parastrephia lucida* and, with low cover, also by *Baccharis tricuneata, B. caespitosa, Senecio nutans* and the caespitose *Ephedra rupestris.* Cacti are represented by the cushion-forming *Cumulopuntia boliviana* subsp. *ignescens. Tetraglochin cristatum* is absent. The vegetation consists of both annual and perennial species.
Syntaxonomy: The character species of the alliance *Azorello-Festucion*, *Azorella compacta* and *Festuca orthophylla* are very frequent. Diagnostic species of this species-

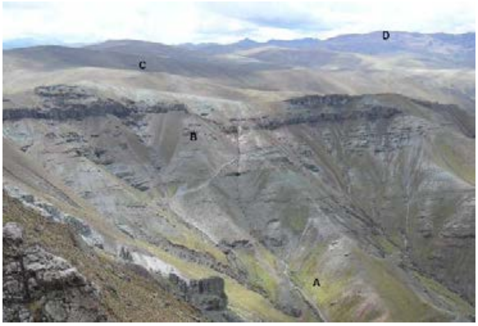


Figure 2. Superpuna landscape at 4500–4800 m (Cachilaya-Yanapuquio sites, Ichuña district). A. Community of *Misbrookea strigosissima* & *Stipa ichu* (*Calamagrostietea vicunarum*). B. *Saxifrago magellanicae-Leucherietum daucifoliae* (*Argyrochosmetea niveae*). C. *Astragalo minimi-Azorelletum diapensioidis wernerietosum melanandrae* (*Calamagrostietea vicunarum*). D. *Nototrichion obcuneatae* (*Anthochloo lepidulae-Dielsiochloetea floribundae*).

Figure 3. Overview of the grasslands with cushions of *Azorella compacta* in the surroundings of the road between Carmen Chaclaya and Matazo in the Ubinas district (4460–4830 m). A. *Astragalo pusillii-Parastrephietum quadrangularis* (*Calamagrostietea vicunarum*). B. *Senecioni moqueguensis-Pycnophylletum molle* (*Calamagrostietea vicunarum*). C. *Plantagini rigidae-Distichietea muscoidis*. D. *Nototrichion obcuneatae* (*Anthochloo lepidulae-Dielsiochloetea floribundae*).

Figure 4. Overview of the extensive slopes with *Senecioni moqueguensis-Pycnophylletum molle mniodetosum pulvinatae* in the surroundings of the group of lakes between the localities of Coalaque and Querala, in the Ubinas district at an altitude of 4550 m. Species visible in the figure: *Azorella compacta* (cushion), *Festuca orthophylla* (tussock grass), *Baccharis tricuneata* and *Parastrephia lucida* (shrubs).

Figure 5. Overview of the scree slopes with cushions of *Azorella compacta* on the lower slopes of Choco-Choco mountain in the Yunga district at 4750 m.

rich association are *Calamagrostis trichophylla, Nototriche mandoniana, Silene mandonii* and *Perezia pungens. Anthochloa lepidula*, considered to be a character species of the *Anthochloo-Dielsiochloetea*, appears to have a very wide syntaxonomic amplitude. *Anthochloa lepidula, Dissanthelium calycinum* and *Senecio rufescens,* character species of the *Nototrichion obcuneatae,* are only present at low frequency. By contrast, *Azorella compacta* and *Baccharis caespitosa*, both character species of the *Azorello-Festucion*, are relatively frequent. Consequently this association is considered to belong to the *Azorello-Festucion* instead of the *Anthochloo-Dielsiochloetea* and *Nototrichion obcuneatae.*

Ecology and distribution: The vegetation of this association is widely distributed on steep rocky slopes and plateaus with clayey-sandy soils and scree. This vegetation grows on the highest peaks and plateaus of the study sites between 4590–4800 m in Yanapuquio (Ichuña district), Laguna Jallpacocha environs (Ubinas district) and Perusa (Yunga district).

mniodetosum pickeringii subass. nov.

(Typus: Rel. 14, col. 5.1, Table 2; col. 5, Table 3; Appendix 5; Figure 5)

Physiognomy and composition: The shrub *Parastrephia lucida* is abundant and covers 8–13%. The cushions *Azorella compacta* are as well represented as *Pycnophyllum molle* and also have a relatively high cover and presence.

Syntaxonomy: This subassociation is differentiated by *Mniodes pickeringii, Senecio* sp.2 (# 3935), *Erigeron lanceolatus, Werneria glaberrima* and *Nototriche pedatiloba*. *Senecio evacoides, Dissanthelium calycinum, Stangea rhizantha, Microsteris gracilis, Caiophora rosulata, Cumulopuntia boliviana* subsp. *ignescens* and *Bartsia elongata* are differentials against the other subassociation.

Ecology and distribution: The vegetation of the subassociation occurs at an altitude of between 4715 and 4800 m on slopes with a mixture of scree and sandy-clay and has a wide distribution on the lower slopes of the Choco-Choco Mountain (Yunga district).

drabetosum soratensis subass. nov.

(Typus: Rel. 20, col. 5.2, Table 2; col. 5, Table 3; Appendix 5)

Physiognomy and composition: This subassociation is characterized by high species diversity; 44 species were recorded from 7 relevés. *Draba soratensis* has high constancy and cover and occurs in combination with *Azorella compacta, Pycnophyllum molle, Parastrephia lucida, Baccharis caespitosa, B. tricuneata, Ephedra rupestris, Belloa piptolepis, Pycnophyllum glomeratum* and *Poa candamoana.*

Syntaxonomy: The *drabetosum soratensis* is differentiated by *Draba soratensis*, a dwarf rosette herb with greenish ciliated leaves and white flowers, and by species such as *Bartsia* sp. (# 3092), *Poa gilgiana, Agrostis breviculmis, Lupinus chilensis* and *Viola granulosa.*

Ecology and distribution: The *drabetosum soratensis* grows between 4590 and 4665 m on the summits and slopes of the mountains north of the Ichuña locality in the Yanapuquio site (Ichuña district).

Anthochloo lepidulae-Dielsiochloetea floribundae Rivas-Martínez & Tovar 1982
The Anthochloo-Dielsiochloetea is highland vegetation characterized by ground rosettes, cushion and dwarf subshrubs, herbs and grasses. Soils are of cryoturbate origin with sparse stoniness and fissures in gelid rocks, located near the vegetation line (Rivas-Martínez & Tovar 1982) in the superpuna region. According to Rivas-Martínez & Tovar (1982) *Anthochloa lepidula* and *Dielsiochloa floribunda* are character species of this class. According to our table, however, although *Anthochloa lepidula* has a higher presence in this class, it appears to have a very wide syntaxonomic amplitude. Although the associations are well represented by character species, these are almost absent from the higher units. This might be due to the very extreme climatic conditions on the mountain summits.

Anthochloo lepidulae-Dielsiochloetalia floribundae Rivas-Martínez & Tovar 1982
This order includes the alliance of *Nototrichion obcuneatae* (Galán de Mera et al. 2003), which combines a series of subnival associations identified in the Andean regions of the Moquegua department. In the general overview, this order occurs in the central Andes of Peru, Bolivia and NW Argentina (Rivas-Martínez & Tovar 1982) above 4600 m.

Alliance: ***Nototrichion obcuneatae*** Galán de Mera, Cáceres & Gonzáles 2003
Physiognomy, composition and distribution: The alliance is found on mobile scree slopes. As a consequence of solifluction, the plants are dispersed in sheltered hollows (Galán de Mera et al. 2003). Based on the distribution of its characteristic elements (*Nototriche obcuneata, Xenophyllum poposum*) it is a criorotropical (dry-humid) alliance of the northern highlands of Peru and Bolivia (Galán de Mera et al. 2003, Brako and Zarucchi 1993, Funk 1997). It is characterized by the presence of ground rosettes with thick roots, resinous shrubs and cushions, herbs and small grasses. The associations belonging to this alliance can further be found in Central Peru (Rivas-Martínez & Tovar 1982), South Peru (Galán de Mera et al. 2003, 2014), NW Bolivia (Seibert & Menhofer 1992), SW Bolivia (Navarro 1993), NW Argentina (Ruthsatz 1997) and the Antofagasta region in Chile (Luebert & Gajardo 2000).
Syntaxonomy: Character species as found in North Moquegua are *Nototriche obcuneata, Senecio rufescens, Senecio* sp.3 (# 3931)*, Dissanthelium calycinum* and *Nototriche* sp.1 (# 3104).
The cryorotropical units here described under the names *Nototricho obcuneatae-Xenophylletum poposi* (Galán de Mera et al. 2003) and *Poo aequiglumae-Xenophylletum dactylophyllum* are similar to those described in Peru (Galán de Mera et al. 2014) and

Bolivia (Seibert & Menhofer 1992, Navarro & Maldonado 2002) as having similar floristic affinities, such as *Anthochloa lepidula, Nototriche obcuneata* and *Senecio rufescens.* Both associations are more similar to those units described in Arequipa by Galán de Mera et al. (2014) and Bolivia (Seibert & Menhofer 1992). Our understanding of the structure of these cryorotropical communities is inadequate because of the lack of studies of the different geographical regions.

Nototricho obcuneatae-Xenophylletum poposi Galán de Mera, Cáceres & Gonzáles 2003
(Col. 6.1–6.2, Table 2; col. 6, Table 3; Appendix 6; Figure 6)
Physiognomy and composition: Sixteen relevés were made, containing 28 species. Plateau vegetation with abundance of cushions represented by *Mniodes coarctata* (5–10 cm height, 40–60 cm of diameter) and the shrubs *Senecio rufescens* (60–80 cm) and *Xenophyllum poposum* (10–20 cm). The vegetation cover is 10–50%. The shrub layer is composed of *Senecio rufescens, Xenophyllum poposum,* and with a lower cover of *Parastrephia lucida* and *Senecio nutans.* In the herb layer cushions are relatively abundant (*Mniodes coarctata, Pycnophyllum molle, P. bryoides*), attaining 10–20% of the total percentage cover. The herbs comprise *Anthochloa lepidula* and *Calamagrostis curvula.*
Syntaxonomy: Character species are *Xenophyllum poposum* and *Mniodes coarctata.* Moreover, *Senecio tassaensis, Pycnophyllum molle, Werneria pectinata, Mniodes pulvinata* and *Astragalus uniflorus* are differential species against the other communities of the *Nototrichion obcuneatae*.
Ecology and distribution: The *Nototricho obcuneatae-Xenophylletum poposi* grows at 4650–4735 m on 2–10° slopes (facing N, NE, NNW, S, SE, SSE, W or WNW). The superficial, stony and bare soils occur on the summits of the Pirhuani peak (Ubinas district), the lower mountain peaks of Choco-Choco (Yunga district) and the scree plateaus of the puna desert of the Janchata lower slopes (Carumas district).

nototrichietosum erinaceae subass. nov.
(Typus: Rel. 6, col. 6.1, Table 2; col. 6, Table 3; Appendix 6)
Physiognomy and composition: By comparison with the other subassociation of the *Nototricho obcuneatae-Xenophylletum poposi*, the vegetation attains higher cover and species richness. Stones (40%) have a higher cover than rocks (4%). The cushion-forming *Pycnophyllum molle, Mniodes coarctata* and *Pycnophyllum glomeratum* are frequent. Tussock grasses are absent. Shrubs are represented by *Senecio nutans* and *Parastrephia lucida,* both with low cover.
Syntaxonomy: This subassociation is differentiated by *Nototriche erinacea, Poa* sp. (# 3099) and *Nototriche* sp.2 (# 4228a). Differentials against the other subassociation are: *Pycnophyllum molle, P. glomeratum, Senecio nutans, S. tassaensis, Parastrephia lucida, Luzula vulcanica* and *Mniodes pulvinata.*

Ecology and distribution: The *nototrichietosum erinaceae* grows between 4650 and 4735 m, on the extensive plateaus (5–10°) of the Pirhuani peak (Ubinas district) and the lower mountain peaks of Choco-Choco (Yunga district). Vegetation cover attains 20–45%; soils are a mixture of clayey sand.

senecionetosum trifurcifolii subass. nov.
(Typus: Rel. 14, col. 6.2, Table 2; col. 6, Table 3; Appendix 6; Figure 7)
Physiognomy and composition: Association of vegetation growing on a mixture of scree and volcanic sand deposits, with low diversity of species and extensive bare soils. It consists of 4–20 cm tall resinous shrubs (*Senecio trifurcifolius*) with a cover of 5–10% in combination with few grasses and herbs attaining less than 5% cover. The cushion *Mniodes coarctata* and mat-forming *Xenophylum poposum* co-occur with a cover of 5–7%.
Syntaxonomy: The description of this subassociation is based on 5 relevés containing 12 vascular species. Character species are *Senecio trifurcifolius* and *Senecio* sp.4 (# 4228b). Differentials against the other subassociation are *Nototriche* sp.1 (# 3104), *Nototriche obcuneata* and *Trisetum spicatum.*
Ecology and distribution: This Andean chasmophyte community is generally found on the extensive plateaus formed by the volcanic lower slopes and locally known as "puna desert". It is located at altitudes of 4700–4710 m (probably extending up to 4800 m), and a slope of 5–10° facing southeast. The soils are mainly formed by scree and white volcanic sand deposits. These communities can be found on the Janchata lower slopes (Carumas district) and presumably also occur on the lower slopes of the Huaynaputina and Ticsani extinct volcanoes. It is worth mentioning that several herds of vicuña (*Vicugna vicugna*) were seen during fieldwork.

Poo aequiglumae-Xenophylletum dactylophyllum ass. nov.
(Typus: Rel. 2, col. 7, Table 2; col. 7, Table 3; Appendix 7)
Physiognomy and composition: Five relevés were made, containing 15 species. Characteristic are the rocky and scree slopes with low vegetation cover and low species diversity. The resinous dwarf shrub *Xenophyllum dactylophyllum* is common, together with the short grass *Anthochloa lepidula* and the ground rosette *Nototriche obcuneata.* Vegetation cover is about 10–15%. Cushion plants are almost absent, except for *Pycnophyllum glomeratum*, which was found in only one relevé, with low cover. Shrubs are represented by *Senecio nutans* and *Parastrephia lucida* with very low cover. Tussock grasses are absent. **Syntaxonomy:** Character species are *Xenophyllum dactylophyllum, Nototriche* sp.3 (# 2447),
Poa aequigluma and *Poa spicigera.*
Ecology and distribution: Criorotropical association with SSW aspect, with extension to an altitude of 4800 m. The association was only found on the Choco-Choco rocky

Figure 6. Overview of the *Nototricho obcuneatae-Xenophylletum poposi* on the summits of Pirhuani peak (4730 m) in the Ubinas district. Occasional snow cover occurs during the rainy season.

Figure 7. Overview of the scree and volcanic sand deposits at the Janchata lower slopes (4700 m) where *Nototricho obcuneatae-Xenophylletum poposi senecionetosum trifurcifolii* occurs.

slopes (Yunga district) and is assumed to occur on other slopes and summits above 4800 m in the neighboring departments in South Peru.

Community of *Senecio algens*

(Representative Rel. 2, col. 8, Table 2; col. 8, Table 3; Appendix 8)
Physiognomy and composition: Nine species were found from 5 relevés. Almost bare scree slopes with low species diversity. The unique appearance of the shrub *Senecio* sp.5 (# 3942) (apparently a new species) is very characteristic of the landscape and the less than 10 cm high *Senecio algens* develops with low cover between the scree stones. 90% of the soils are formed by white scree and rarely by rocks (except in one relevé). Vegetation cover is about 5%, the slope is 35–45°, facing W or NW.
Syntaxonomy: Characteristic species are *Senecio algens* and *Senecio* sp.5 (# 3942). *Stangea rhizantha* is differential against the other units of the alliance.
Ecology and distribution: Criorotropical association distributed between 4740 and 4760 m. The community was only found on the Choco-Choco scree slopes (Yunga district) and is assumed to occur on other mountain summits above 4700 m in the neighboring departments of South Peru. Galán de Mera et al. (2014) recognized the occurrence of the community at lower altitude with a mixture of species belonging to grasslands. Cano et al. (2011) indicates that *S. algens* can be found on chasmophytic rocky slopes as well as in crioturbate conditions.

Nitrophytic community

Diagnosis: Nitrophytic communities dominated by nitrophytes growing in pats of llama and alpaca dung in grassland plateaus and slopes in the South Andes of Peru. Little is known about the occurrence of these specific plant communities in the Andes.

It seems that populations of *Urtica flabellata* are widespread (Gutte 1995). Weberbauer (1945) mentions *Urtica flabellata* as a ruderal species and colonizer of pats of llama dung that can often be found in puna regions together with *Cajophora cirsiifolia* and tall *Lupinus* sp. plants. Communities from this class, but floristically more impoverished, can also be recognized in Northern and Central Peru, and Bolivia (Gutte 1986, 1995, Seibert & Menhofer 1992). The ecological and floristical optimum for this class is found in the orotropical and criorotropical bioclimatic belts. The distribution range of the class is approximately between 4000–4800 m. Diagnostic species: *Urtica flabellata.* Furthermore, Galán de Mera et al. (2012b) describe the close affinity of these communities to the class *Nicotiano glutinosae-Ambrosietea arborescentis* Galán de Mera & Cáceres in Galán de Mera, Rosa & Cáceres (2002a), which represents ruderal vegetation from lower altitudes with a very distinct structure and composition.
In the prepuna in Central Peru (Prov. Yauli, dept. Junín) Gutte (1986) described the *Urtico flabellatae-Cajophoretum sepiariae* between 3600 and 3800 m in the region South of La Oroya. He supposed that this association could belong to a still undescribed class *Urticetea flabellatae* (class. nov. prov.). He made additional observations of alpine *Urtica flabellata* communities on the West slope of the Andes between 3000 and 3600 m, above Huánuco 3900–4000 m, in North Peru above Cajamarca and near Huaraz and Cusco. We agree with the concept of Gutte that a true ruderal class seems to exist in the alpine zone of Peru. However, in our relevés of the superpuna of Moquegua the only species in common with Gutte (1986) are the character species *Urtica flabellata* and *Perezia multiflora*. *Urtica flabellata* and *Solanum acaule* are also shared with the *Urtico flabellatae-Urocarpidetum peruviani* Galán de Mera et al. (2012b) (3320–3850 m). For an adequate description of the class on the level of order and alliances, more relevés are needed throughout the country and also from neighbouring Bolivia.
It is known that *Urtica flabellata* also occurs in the páramos of Ecuador and Colombia (Cleef 1981). On calcareous bedrock (Colombian Páramo Almorzadero) *Lachemilla pinnata* is associated with *Urtica flabellata* as well. The communities have been found in rock shelters, where cattle and wildlife shelter during the night and heavy rain, and near traditional cattle corrals and farmhouses. Thus far there are no relevés available for páramos. We conclude that these communities need further research using relevé data collection from both puna and páramo.

Community of *Tarasa nototrichoides* and *Urtica flabellata*

(Representative relevé: 2, col. 7, Table 2; col. 9, Table 3; Appendix 9; Figure 7)
Physiognomy, composition and syntaxonomy: Nitrophytic community growing on llama and alpaca dung pats in grassland plateaus near grazing sites. The vegetation typically develops during the rainy season within a short 2–3-month period. Due to the nitrogen-rich accumulations of manure, species such as *Urtica flabellata* become dominant; in some areas, together with other species, it covers almost 100% of the

soil surface. The diagnostic species *Urtica flabellata, Solanum acaule and Valeriana* sp. (Image DSC075, 03/2014) have only been found in this association. Other diagnostic species are *Lachemilla pinnata, Perezia multiflora* and *Tarasa nototrichoides. Dissanthelium calycinum* occurs in all relevés.

Ecology and distribution: The community of *Tarasa nototrichoides* and *Urtica flabellata* can be found between 4460 to 4650 m in North Moquegua, in a wide variety of habitats. Tropicos (2014) includes the distribution of *Urtica flabellata* in the high Andes from Colombia to Argentina; therefore this puna and superpuna association can be assumed to occur in a wide geographical area in the high Andes.

Gradients and zonation

The DCA diagrams (figures 9, 10) show the relation between the plant communities and environmental variables. In figure 9, the main gradient in species composition (axis 1) is strongly correlated with altitude (r= 0.65), scree (r= 0.31), vegetation cover (r= –0.24), grazing (r= –0.22), manure (r= –0.16), stones (r= 0.03) and number of species (r= –0.06). The relation between the second axis and environmental variables is low, except for number of species (0.34), vegetation cover (r= 0.31) and slope inclination (r= 0.27).

The grasslands with cushions (*Astragalo pusillii-Parastrephietum quadrangularis* and *Astragalo minimi-Azorelletum diapensioidis*) are positively correlated with grazing, number of species, vegetation cover and manure. The cushion community (*Senecioni moqueguensis-Pycnophylletum molle*) is correlated with rocks, altitude and scree. The other cushion communities from higher altitudes (*Calamagrostio trichophyllae-Azorelletum compactae*) are correlated with altitude, percentage of stones, slope and rocks.

In figure 10, the main gradient in species composition (axis 1) is strongly correlated with vegetation cover (r= 0.81), manure (r= 0.88), stone percentage (r= –0.57), scree (r= –0.56),

Figure 8. Detail of *Urtica flabellata* among llama and alpaca dung at 4460 m.

number of species (r= –0.54), slope inclination (r= –0.43), altitude (r= –0.31), grazing (r= –0.28), and rock percentage (r= –0.16). The relation between the second axis and environmental variables is relatively low except, for inclination (r= 0.67), grazing (r= –0.29), scree (r= 0.25), altitude (r= 0.20) and number of species (r= –0.19). The nitrophytic community of *Tarasa nototrichoides* and *Urtica flabellata* is positively correlated with manure and vegetation cover and negatively correlated with stones, scree, slope, number of species and rock percentage. The chasmophytic unit, *Saxifrago magellanicae-Leucherietum daucifoliae*, plotted on the lower side of axis 2 is positively correlated with number of species, stones, slope and scree but negatively with manure and vegetation cover.
The *Nototricho obcuneatae-Xenophylletum poposi* correlated positively with number of species and negatively with manure and vegetation cover. The community of *Senecio algens* shows a positive correlation with scree, stone percentage and slope degree.

The relation between vegetation and environmental factors as shown by the ordination diagrams is confirmed by figure 11 in which the mean values for (a) slope degree, (b) vegetation cover, (c) rocks and (d) stones are given. As can be expected, *Calamagrostio trichophyllae-Azorelletum compactae mniodetosum pickeringii* develops on steeper slopes, as does the community of *Senecio algens.* In contrast, the community of *Tarasa nototrichoides* and *Urtica flabellata* develops on level surfaces. In graph b, vegetation cover is higher in the following units: community of *Tarasa nototrichoides* and *Urtica flabellata, Astragalo pusillii-Parastrephietum quadrangularis astragaletosum pusillii, Astragalo*

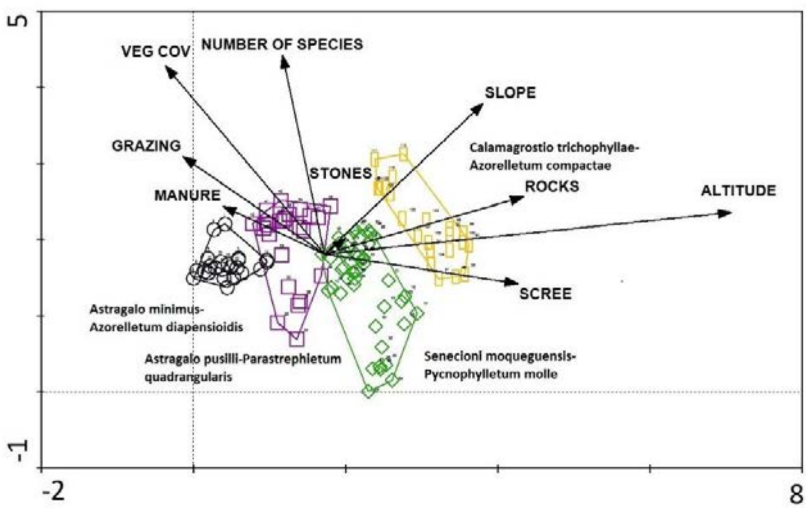


Figure 9. Ordination diagram (DCA, axis 1 and 2) of communities 2–5. The relevés belonging to the 4 different associations have been delineated. # SPP refers to the total number of species, % rocks and stones = estimated cover of rocks and stones in each relevé. VC refers to total vegetation cover, altitude is expressed in meters above sea level, manure and grazing is expressed in I: 1–30%; II: 31–70%; III: >71%, and scree is expressed by the percentage total cover.

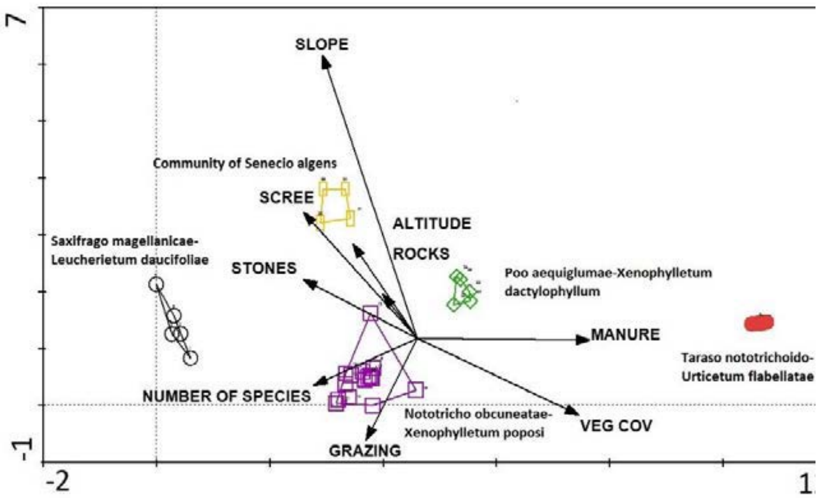


Figure 10. Ordination diagram (DCA, axis 1 and 2) of communities 1, 6–9. The relevés of three associations, one community and one provisional association have been delineated. For caption definitions refer to figure 9.

minimi-Azorelletum diapensioidis aciachnetosum pulvinatae and *Senecioni moqueguensis-Pycnophylletum molle mniodetosum pulvinatae*. The lowest vegetation cover (less than 20%) was recorded for the community of *Senecio algens, Nototricho obcuneatae-Xenophylletum poposi senecionetosum trifurcifolii, Poo aequiglumae-Xenophylletum dactylophyllum* and *Astragalo pusillii-Parastrephietum quadrangularis sisyrinchietosum trinervis. Astragalo pusillii-Parastrephietum quadrangularis* (3.1, 3.2 and 3.3 in figure 11) grows on sites with a high rock cover. This is especially the case in two subassociations belonging to this association: the *sisyrinchietosum trinervis* and *baccharidetosum tricuneatae*. The mean rock cover is less than 10% in the *Saxifrago magellanicae-Leucherietum daucifoliae* (comm. 1), *Astragalo pusillii-Azorelletum diapensioidis* (comm. 2) and community of *Senecio algens* (comm. 8). The community of *Tarasa nototrichoides* and *Urtica flabellata* (comm. 9) grows on sites without bare rock.
In the community of *Senecio algens* (comm. 8) the surface is almost fully covered by stones (>90%) as well as in the *Nototricho obcuneatae-Xenophylletum poposi senecionetosum trifurcifolii*. Within the *Saxifrago magellanicae-Leucherietum daucifoliae* (comm. 1) the stone cover is 40-50%. Stones are almost absent in the community of *Tarasa nototrichoides* and *Urtica flabellata* (comm. 9).

Figure 12 shows the observed and expected altitudinal distribution of the syntaxa described in this overview. The gray boxes represent the distribution as based on the present field survey and the boxes in dashed lines the expected distribution based on the co-occurrence of the following character species of the syntaxa distinguished (Montesinos-Tubée 2011a, 2012a, 2013b, 2014b): *Saxifraga magellanica* with *Leucheria*

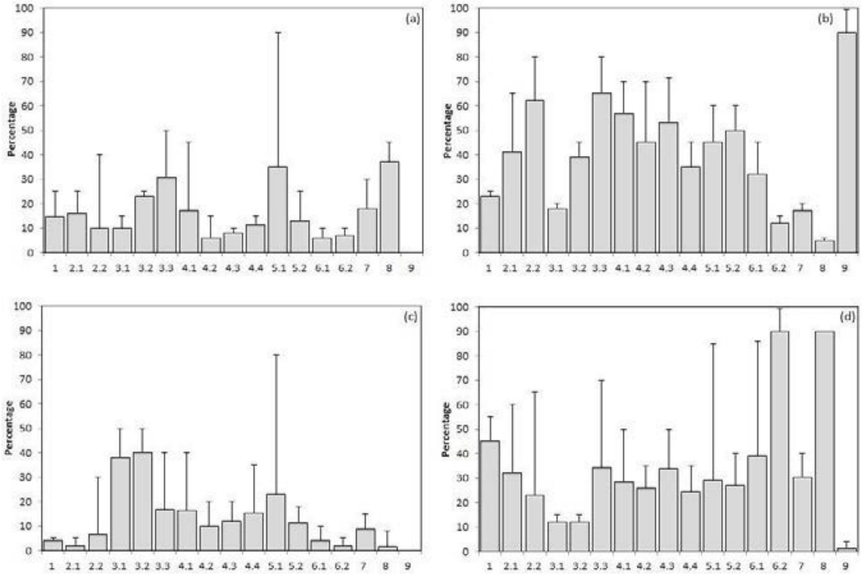


Figure 11. Bar charts showing the mean percentage values with standard deviation for (a) slope degree, (b) vegetation cover, (c) rocks and (d) stones.

daucifolia; *Astragalus minimus* and *Azorella diapensioides*; *Senecio nutans* and *Parastrephia quadrangularis*; *Senecio moqueguensis* together with *Azorella compacta*; *Anthochloa lepidula* and *Azorella compacta*; *Nototriche obcuneata* with *Xenophyllum poposum*; *Xenophyllum dactylophyllum*; *Senecio algens*; *Dissanthelium calycinum* with *Urtica flabellata*. The expected altitudinal distribution of the different communities is as follows: (1) *Saxifrago magellanicae-Leucherietum daucifoliae* (4500–4800 m), (2) *Astragalo minimi-Azorelletum diapensioidis* (4350–4700 m), (3) *Astragalo pusillii-Parastrephietum quadrangularis* (4250–4650 m), (4) *Senecioni moqueguensis-Pycnophylletum molle* (4500–4800 m), (5) *Calamagrostio trichophyllae-Azorelletum compactae* (4550–4800 m), (6) *Nototricho obcuneatae-Xenophylletum poposi* (4600–4800 m), (7) *Poo aequiglumae-Xenophylletum dactylophyllum* (4750–4950 m), (8) Community of *Senecio algens* (4450–4800 m) and (9) community of *Tarasa nototrichoides* and *Urtica flabellata* (4200–4700 m).

Floristic composition and diversity

In total, 172 vascular species belonging to 80 genera and 32 families were recorded. The flora list of the total relevé dataset Asteraceae (60 spp.) is dominated by Malvaceae (14 spp.), Poaceae (14 spp.), Brassicaceae (11 spp.), Caryophyllaceae (10 spp.), Fabaceae (9 spp.) and Apiaceae (4 spp.). The shrubs (woody, postrate or erect, 5–70 cm height) are represented by 26 species, herbs (including rosettes) by 93 species, cushions by 14 species, mat-forming plants by 22 species, grasses by 13 species), and ferns and succulents by one species each.

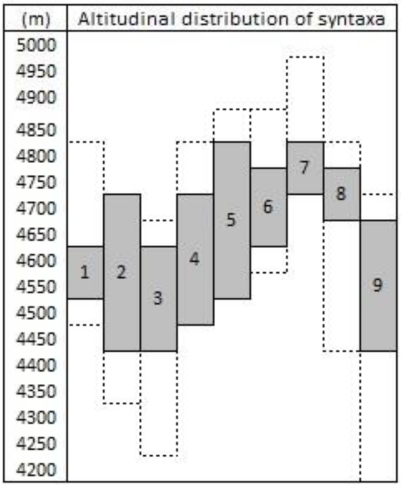


Figure 12. Altitudinal distribution of syntaxa (association, subassociation) and communities of the study area based on the relevés (solid lines) and references and field observations (dashed lines) from Moquegua by the first author (Montesinos-Tubée 2011a, 2012a, 2013b, 2014b). (1) *Saxifrago magellanicae-Leucherietum daucifoliae,* (2) *Astragalo minimi-Azorelletum diapensioidis,* (3) *Astragalo pusillii-Parastrephietum quadrangularis,* (4) *Senecioni moqueguensis-Pycnophylletum molle,* (5) *Calamagrostio trichophyllae-Azorelletum compactae,* (6) *Nototricho obcuneatae-Xenophylletum poposi,* (7) *Poo aequiglumae-Xenophylletum dactylophyllum,* (8) Community of *Senecio algens,* (9) community of *Tarasa nototrichoides* and *Urtica flabellata.*

In figure 13, box-and-whisker plots show the species diversity of the different communities. Chasmophytic and nitrophytic communities have low diversity of species, with the exception of community 1 (*Saxifrago magellanicae-Leucherietum daucifoliae*), which has a maximum of 15 species and a median of 11 species. The highest species diversities were recorded in the *Senecioni moqueguensis-Pycnophylletum molle* (comm. 4) and *Calamagrostio trichophyllae-Azorelletum compactae* (comm. 5), which have a median of 15 species and a maximum of 26 and 25 species respectively. Within the grasslands with cushions, species diversity in the *Astragalo minimi-Azorelletum diapensioidis* (comm. 2, median of 18 species and maximum of 23 species) is greater than that of the *Astragalo pusillii-Parastrephietum quadrangularis* (comm. 3), median of 13 species and maximum of 22 species. The species diversity is least in the *Nototricho obcuneatae-Xenophylletum poposi* (comm. 7) and community of *Senecio algens* (comm. 9), with a median of 6 species and maximum of 16 species; this is probably due to the extreme conditions in their high altitude growth sites.

Floristic composition

The floristic composition and diversity of the Andean grasslands of Moquegua change with altitude. Family composition shows the same trend as observed in the Andean

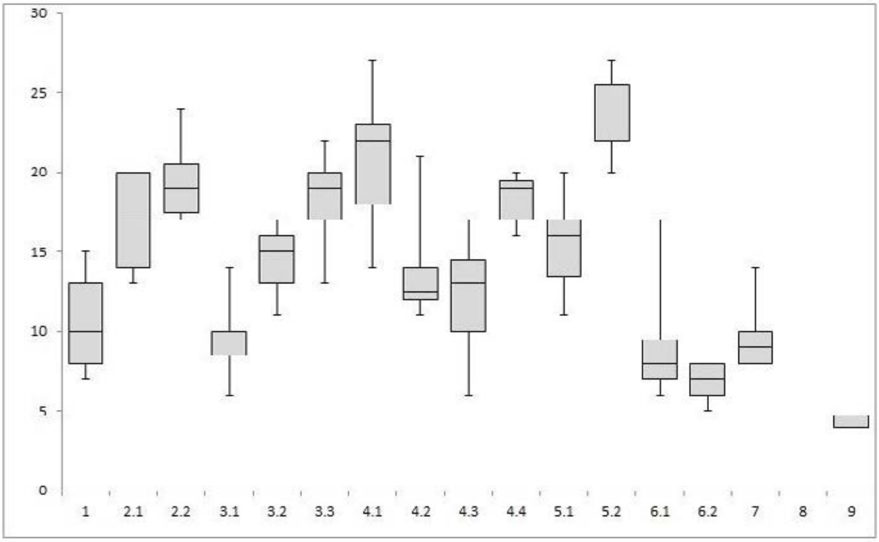


Figure 13. Box-and-whisker plots representing species richness per community in chasmophyte vegetation (1), grasslands with cushions (2–4), cushion communities (5–8) and one nitrophytic unit (9). The line in the boxes represents the median values, the boxes the 25 and 75% percentiles and the lines the minimum and maximum values found in each community.

prepuna and puna of Moquegua (Montesinos et al. 2012, Montesinos-Tubée et al. 2015b), where the Composites dominate the vegetation. In the grasslands of Moquegua, species richness is greatest within the woody species belonging to the Composites, Fabaceae and Orobanchaceae, while in the ground layer the number of species is highest in the Malvaceae, Caryophyllaceae and Poaceae, followed by Plantaginaceae and Violaceae.
Species diversity and composition show variation caused by slope exposure, rockiness and stoniness. In the chasmophytic communities, species richness generally decreases with elevation. However, species richness was observed to increase locally between 4500 and 4700 m in the cushion communities, probably as a result of nursing effects, sometimes in great abundance as seen in *Azorella* and *Pycnophyllum* (Catorci et al. 2014, Montesinos-Tubée 2015a). Although lichens and mosses were not included in our phytosociological analysis, we noted their low diversity in the study sites. Low cover of *Thamnolia vermicularis* was observed in the *Poo aequiglumae-Xenophylletum dactylophyllum*.

Floristic affinity with previously published syntaxa.

The similarity between our communities and related communities as decribed in literature is shown in a dendrogram (figure 14). The first 9 clades represent the communities from the present study: chasmophyte vegetation (1) chasmophytes, grasslands with cushions and cushion communities (2–L4), highland plateaus and summits (6–L8), and the nitrophytic unit (9). The other 18 columns represent communities from the Andes

described by Galán de Mera et al. (2003, 2011b, 2014). The chasmophytic unit of *Saxifrago magellanicae-Leuchaerietum daucifoliae* (1) is related to the plateau communities with cushions where *Xenophyllum dactylophyllum* is present (7) and to such communities without cushions (8). The Moquegua grassland units with cushions are represented by L2–L5; these show correlation with *Parastrephio lucidae-Festucetum orthophyllae* (10) (Galán de Mera et al. 2003) and *Senecioni nutantis-Parastrephietum quadrangularis* (11) (Galán de Mera et al. 2011b). The assignement of the *Calamagrostio trichophyllae-Azorelletum compactae* to the *Azorello-Festucion* is confirmed by the dendrogram. The next group consists of *Nototrichion obcuneatae* communities containing the plateau units where *Nototricho obcuneatae-Xenophylletum* poposi (this study: L6) occurs (South Peru and northwest Bolivia) and is related to Nototricho *obcuneatae-Mniodetum coarctatae* (26), *Nototricho obcuneatae-Xenophylletum poposi* (25), *Wernerio aretioidis-Parastrephietum lucidae* (27) (Galán de Mera et al. 2014) and *Nototricho obcuneatae-Xenophylletum ciliolatae* (24).
The superpuna plateaus represented by L1 (chasmophytic unit), L7 and L8 in our study are put in a group that differs greatly from the groups described in literature, where the correlation is more with the *Xenophyllum* units described by Galán de Mera et al. (2014) and Seibert & Menhofer (1992).
All other remaining communities appear to be very dissimilar to the clusters described above. The nitrophytic unit presented in this study (L9) is the least similar with any of the other groups.

There are few previous studies on species composition and diversity of superpuna grassland communities in South Peru for comparison with our vegetation description. Gutte (1985, 1986, 1987) and Galán de Mera et al. (2003, 2011b, 2012b, 2014) address the phytosociological classification and description of plant communities in the central and southern Peruvian Andes. Other studies from North Chile (Luebert & Gajardo 2000, 2005) and Bolivia (Seibert & Menhofer 1991, 1992, 1993; Navarro 1993; Navarro & Maldonado 2002) were compared with our results and appear to differ significantly in species composition and distribution. Montesinos et al. (2012), Montesinos-Tubée et al. (2015b) describe the prepuna shrublands, puna chasmophytes and grassland communities occurring in the north of Moquegua under the classes *Echinopsio-Proustietea cuneifoliae* (prepuna shrublands) occurring at an average altitude of 3500 m, *Argyrochosmetea niveae* (chasmophytic vegetation) and *Calamagrostietea vicunarum* (puna grasslands) occurring between 3800 and 4500 m. These communities lack the presence of cushion plants (*Azorella compacta, Pycnophyllum* spp.) and the tussock grass represented by *Festuca orthophylla.*

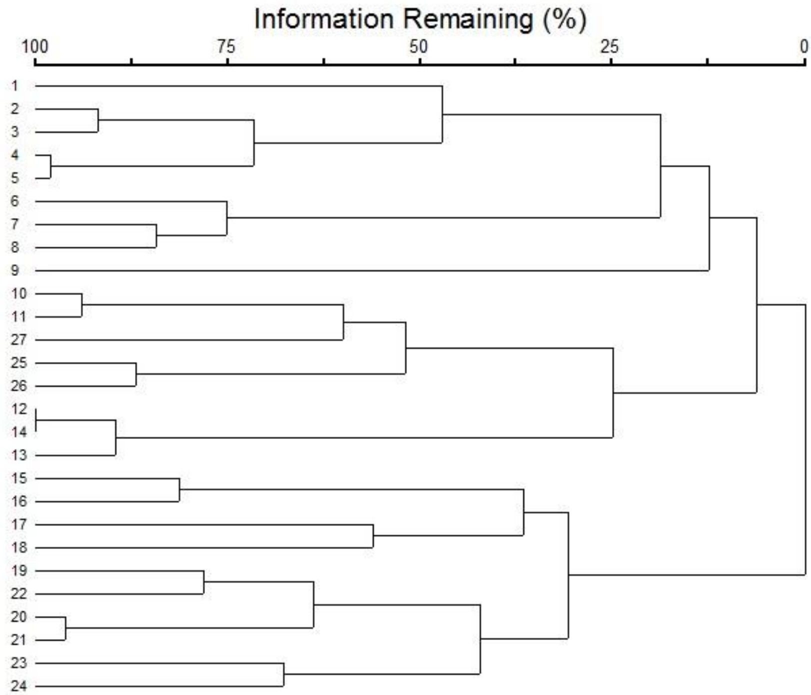


Figure 14. PC-ORD dendrogram analysis of 27 clusters (weighted by presence class) and based on 229 plant species (see methods and appendix 1 for the synoptic table). 1. *Saxifrago magellanicae-Leucherietum daucifoliae*, 2. *Astragalo minimi-Azorelletum diapensioidis*, 3. *Astragalo pusillii-Parastrephietum quadrangularis*, 4. *Senecioni moqueguensis-Pycnophylletum molle*, 5. *Calamagrostio trichophyllae-Azorelletum compactae*, 6. *Nototricho obcuneatae-Xenophylletum poposi* (Galán de Mera et al. 2003), 7. *Poo aequiglumae-Xenophylletum dactylophyllum*, 8. Community of *Senecio algens*, 9. community of *Tarasa nototrichoides* and *Urtica flabellata* (this study), 10. *Parastrephio lucidae-Festucetum orthophyllae festucetosum orthophyllae, azorelletosum compactae, polylepidetosum tarapacanae, Stipa ichu* BC, *Pycnophyllum molle* BC (Galán de Mera et al. 2003), 11. *Senecioni nutantis-Parastrephietum quadrangularis* (*Calamagrostietea vicunarum, Parastrephietalia lepidophyllae, Azorello-Festucion*) (Galán de Mera et al. 2011b), 12. *Parastrephio quadrangularis-Festucetum dolichophyllae* (Galán de Mera et al. 2011b), 13. *Parastrephio quadrangularis-Festucetum dolichophyllae festucetosum orthophyllae* (Galán de Mera et al. 2011b), 14. *Parastrephio quadrangularis-Festucetum dolichophyllae agrostietosum gelidae* (Galán de Mera et al. 2011b), 15. Community of *Senecio algens* (Galán de Mera et al. 2014), 16. *Senecioni culcitioides-Valerianetum nivalis*. *Draba brackenridgei* race I (Galán de Mera et al. 2014), 17. *Senecioni culcitioides-Valerianetum nivalis*. *Draba cryptantha* race I (Galán de Mera et al. 2014), 18. *Senecioni culcitioides-Valerianetum nivalis*. *Draba cryptantha* race II (Galán de Mera et al. 2014), 19. *Senecioni culcitioides-Valerianetum nivalis*. *Draba brackenridgei* race II (Galán de Mera et al. 2014), 20. *Senecioni culcitioides-Valerianetum nivalis*. *Draba cuzcoensis* race (Galán de Mera et al. 2014), 21. *Senecioni culcitioides-Valerianetum nivalis mniodetosum andinae* (Galán de Mera et al. 2014). 22. *Senecioni culcitioides-Valerianetum nivalis* s*axifragetosum magellanicae* (Galán de Mera et al. 2014), 23. *Xenophyllo ciliolati-Plettkeetum cryptanthae, Chaetanthera cochlearifolia BC, Stangeo rhizanthae-Weberbaueretum rosulantis* (Galán de Mera et al. 2014), 24. Community of *Poa gymnantha-*

Cerastium subspicatum; *Valeriana globularis-Anthochloa lepidula* DC; Community of *Caiophora horrida-Senecio rufescens*: Community of *Xenophyllum dactylophyllum*; *Nototricho obcuneatae-Xenophylletum ciliolatae*, 25. *Nototricho obcuneatae-Xenophylletum poposi* (incl. *valerianetosum, mniodetosum*), 26. *Nototricho obcuneatae-Mniodetum coarctatae*, 27. *Wernerio aretioidis-Parastrephietum lucidae* (Galán de Mera et al. 2014).

Concluding remarks

Our vegetation research in northern Moquegua (South Peru), an area not studied previously, extends the knowledge of the syntaxonomy, floristic diversity and synecology of *Azorella compacta* and *Pycnophyllum molle* vegetation structure, and of chasmophytic and nitrophytic communities. It comprises four alliances, seven new associations and thirteen subassociations, representing an important basis for a future overview and synopsis of the Andean vegetation of South America. The vegetation studied in Moquequa appears to be floristically different from comparable vegetation in North Chile and Bolivia. Further research is needed, however, to study the relation with chasmophytic and plateau associations with cushions in the highlands of other mountainous regions in South America.

The present overview is also important as a reference and tool for nature conservation. Apart from the impressive cushions plants, many other endemic species are found in the newly described syntaxa, increasing the need for conservation schemes and measures. In recent years, the superpuna communities have been increasingly affected by grazing and road construction. The natural vegetation is being disturbed and cushions of *Azorella compacta* have regularly been removed for use as fuel. Fire has been regularly observed on several mountain slopes. These fires were probably set on purpose as part of a festivity in June. Fortunately, due to advice and information given to the local communities by the first author, this practice is now gradually decreasing (personal observation), and conservation programs have been started. At the same time, interviews with the local communities suggest that the pastures are being grazed in a way that prevents overgrazing. Negative effects have been observed only in some grassland communities where livestock and wild grazers are abundant. In addition to livestock, wild grazers including vicuñas (*Vicugna vicugna*), viscacha (*Lagidium peruanum*), taruca (*Hippocamelus antisensis*) and suri (lesser rhea, *Rhea pennata*) are known to occur in the region. This highlights the vulnerability of the flora and vegetation of the Andes to human pressure, and requires further studies.

Table 3. Synoptic table with percentage constancy (frequency) values (1–100%). # Order refers to the community number (this study and literature). # REL refers to the total number of relevés in that unit and #SPP to the total number of species in that unit. 1. ***Saxifrago magellanicae-Leucherietum daucifoliae***, 2. ***Astragalo minimi-Azorelletum diapensioidis***, 3. ***Astragalo pusillii-Parastrephietum quadrangularis***, 4. ***Senecioni moqueguensis-Pycnophylletum molle***, 5. ***Calamagrostio trichophyllae-Azorelletum compactae***, 6. ***Nototricho obcuneatae-Xenophylletum poposi*** (Galán de Mera et al. 2003), 7. ***Poo aequiglumae-Xenophylletum dactylophyllum***, 8. Community of ***Senecio algens***, 9. Community of ***Tarasa nototrichoides*** and ***Urtica flabellata*** (this study), 10. ***Parastrephio lucidae-Festucetum orthophyllae festucetosum orthophyllae, azorelletosum compactae, polylepidetosum tarapacanae, Stipa ichu*** BC, ***Pycnophyllum molle*** BC (Galán de Mera et al. 2003), 11. ***Senecioni nutantis-Parastrephietum quadrangularis*** (***Calamagrostietea vicunarum, Parastrephietalia lepidophyllae, Azorello-Festucion***) (Galán de Mera et al. 2011b), 12. ***Parastrephio quadrangularis-Festucetum dolichophyllae*** (Galán de Mera et al. 2011b), 13. ***Parastrephio quadrangularis-Festucetum dolichophyllae festucetosum orthophyllae*** (Galán de Mera et al. 2011b), 14. ***Parastrephio quadrangularis-Festucetum dolichophyllae agrostietosum gelidae*** (Galán de Mera et al. 2011b), 15. Community of ***Senecio algens*** (Galán de Mera et al. 2014), 16. ***Senecioni culcitioides-Valerianetum nivalis***. ***Draba brackenridgei*** race I (Galán de Mera et al. 2014), 17. ***Senecioni culcitioides-Valerianetum nivalis***. ***Draba cryptantha*** race I (Galán de Mera et al. 2014), 18. ***Senecioni culcitioides-Valerianetum nivalis***. ***Draba cryptantha*** race II (Galán de Mera et al. 2014), 19. ***Senecioni culcitioides-Valerianetum nivalis***. ***Draba brackenridgei*** race II (Galán de Mera et al. 2014), 20. ***Senecioni culcitioides-Valerianetum nivalis***. ***Draba cuzcoensis*** race (Galán de Mera et al. 2014), 21. ***Senecioni culcitioides-Valerianetum nivalis mniodetosum andinae*** (Galfán de Mera et al. 2014). 22. ***Senecioni culcitioides-Valerianetum nivalis saxifragetosum magellanicae*** (Galán de Mera et al. 2014), 23. ***Xenophyllo ciliolati-Plettkeetum cryptanthae, Chaetanthera cochlearifolia BC, Stangeo rhizanthae-Weberbaueretum rosulantis*** (Galán de Mera et al. 2014), 24. Community of ***Poa gymnantha-Cerastium subspicatum***; ***Valeriana globularis-Anthochloa lepidula*** DC; Community of ***Caiophora horrida-Senecio rufescens***: Community of ***Xenophyllum dactylophyllum***; ***Nototricho obcuneatae-Xenophylletum ciliolatae***, 25. ***Nototricho obcuneatae-Xenophylletum poposi*** (incl. ***valerianetosum, mniodetosum***). 26. ***Nototricho obcuneatae-Mniodetum coarctatae***, 27. ***Wernerio aretioidis-Parastrephietum lucidae*** (Galán de Mera et al. 2014).

#order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
# rel	5	24	23	43	22	16	5	5	10	23	8	8	6	5	2	5	2	1	7	18	8	5	8	21	12	11	9
# spp	19	68	73	94	59	28	14	9	7	50	38	45	32	26	7	22	8	9	22	19	14	24	59	51	18	34	18
Argyrochosmetea niveae																											
Saxifragetalia magellanicae, Saxifragion magellanicae																											
Saxifraga magellanica	100														2	3	1	1				80	13				
Saxifrago magellanicae-Leucherietum daucifoliae																											
Leucheria daucifolia	100																						25				
Weberbauera sp. (# 3842)	60																										
Gentianella incurva	40																										
Perezia pinnatifida	40			5																			25				
Valeriana coarctata	40			2																		20					
Calamagrostietea vicunarum																											
Calamagrostis vicunarum		33	52	53	18					61	50	50	67	20						6	13		50	2	2	4	
Parastrephietalia quadrangularis																											
Parastrephia quadrangularis		13	83	2						65	100	88	100	40												+	1
Tetraglochin cristatum		92	35	14						43	13	63	83	60													2
Descurainia depressa	60	8	13	7																							
Pycnophyllum molle	40	100	43	93	68	38				57			50							11	25		13		2	2	+
Hypochaeris meyeniana	60	50	70	30	14						13													1		1	
Ephedra rupestris	20	8	9	26	32					30	25		67				1							1			
Weberbauera spathulifolia	60	4	26	16	18											1			14			40					
Belloa piptolepis		38	65	51	32	6				30	13					+				6		20			+	1	
Senecio candollei		4	17	37	5															44	13			2			
Senecio humillimus		13	22	14	18																		25	1			1
Brayopsis monimocalyx		46	4	33	23																						
Chaetanthera stuebelii	20			44	23																						
Nototriche anthemidifolia		58		49	64																						
Draba macleanii		17		28	18																		63				
Erigeron rosulatus		25		37	18																						

# order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Erigeron rosulatus		25		37	18																						
Hypochaeris eriolaena		13		12									17														
Plantago sericea var. *lanuginosa*		8	13		23																						
Werneria aretioides		38		42						13																	4
Senecio spinosus		29	26	9						39	13	25	33	40													+
Werneria pectinata		46	17	23		6				4														1			
Silene genovevae		33	22	7																							
Perezia coerulescens		13	13	9						4	13								43	6	25		38	1		+	
Wahlenbergia peruviana		13	17																14								
Nototriche digitulifolia		8	22	5																							
Nototriche pedicularifolia		29		16																						1	
Lupinus ananeanus		8	26	5																							
Cerastium subspicatum		21	22	5																				2			
Conyza deserticola		8	9																								
Lobivia maximiliana			9																								
Oxalis calachaccensis		8																									
Gomphrena meyeniana		8												20													
Calamagrostion minimae																											
Calamagrostis minima		29																					13	2	+		
Werneria nubigena		17																				20					
Oreomyrrhis andicola		42																						1			
Calandrinia acaulis	80	13		19												+								4			
Astragalo minimi-Azorelletum diapensioidis																											
Azorella diapensioides		67	9								13		50											1		+	
Astragalus minimus		83	26	2																							
Bougueria nubicola		67	17	5																							
Werneria apiculata		58	4							13																	
Werneria melanandra		38																									
Nototriche longirostris		38	13																							1	
Junellia minima		29																									
Aciachne pulvinata		46	4							4																	
Nototriche turritela		63									25															1	3
Ourisia muscosa		13																									
Viola hillii		4																									
Azorello compactae-Festucion orthophyllae																											
Azorella compacta			78	74	77	10				48	88										38				1	4	+
Festuca orthophylla		63	22	51	46					100	100		50											1	+	2	4
Baccharis caespitosa			13	12	36					9	13		17			+	1		43			20	38	3	+	+	
Belloa sp. (# 3945)			17	7	27																						
Bowlesia tropaeolifolia			4	2	18											+			43	6		20					
Baccharis tricuneata			35	33	46					22	75	75	33	100												1	
Cumulopuntia boliviana subsp. *ignescens*			22		14					43		25		20													+
Bartsia elongata				9	14							25		40													
Caiophora rosulata				9	18																						
Senecio evacoides				2	32									20					14		25						
Stangea wandae				16	27																						
Astragalo pusillii-Parastrephietum quadrangularis																											
Astragalus pusillus			65							4																3	
Sisyrinchium brevipes		8	22																								
Sisyrinchium trinervis			17																								
Conyza sp. (# 2601)			17																								
Valeriana aschersoniana			4																								
Belloa longifolia			4								13	50		20										1			
Descurainia sp. (# 0940)			4																								
Junellia sp. (# 4019)			4																								
Senecioni moqueguensis-Pycnophylletum molle																											
Senecio moqueguensis				84																							
Senecio tassaensis			4	26		13																					
Nototriche argentea				21	5																						1
Arenaria acaulis				16																							
Gentianella primuloides				16																							
Nototriche sepaliloba				16																							
Cerastium behmianum				14																							
Xenophyllum weddellii				14																							
Nototriche pusilla				12																							
Oritrophium sp. (# 2194b)				12																							
Senecio sykorae				12																							
Perezia coerulescens var. *amplibracteata*				9																							
Werneria heteroloba				9																							
Myrosmodes sp. (# 2287)				7																							
Poa brevis				7																							
Senecio graveolens				7						4	13		17										13				
Senecio sp.1 (# 4217a)				7																							
Spergularia andina		4		7																							
Lupinus sp. (# 2424)				5																							
Senecio bolivarianus				5																							
Viola sp. (# 4217a)				5																							
Werneria sp. (# 3940)				5																							
Xenophyllum digitatum				5																							

#order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Calamagrostio trichophyllae-Azorelletum compactae																											
Nototriche mandoniana					77																						
Calamagrostis trichophylla					77																						
Mniodes pickeringii					68	6																					
Silene mandonii					68																						
Senecio sp.2 (# 3935)					64																						
Erigeron lanceolatus					46																						
Werneria glaberrima				9	41																						
Nototriche pedatiloba					36																						
Perezia pungens					36							25		20													
Draba soratensis					32																						
Bartsia sp. (# 3092)				2	18																						
Poa gilgiana					18											2						60					
Agrostis breviculmis					14																						
Viola granulosa					14																					1	
Lupinus chilensis					5																						
Anthochloo-Diesliochloetea																											
Anthochloa lepidula	40	13		5	9	94	80	40			13												25	4	+	+	
Dielsiochloa floribunda				5		31	60	60		4													88	1		4	
Nototrichion obcuneatae (Nototricho obcuneatae-Xenophylletum poposi)																											
Nototriche obcuneata						6	60	20		9														2	1	4	
Senecio rufescens				5	14	56	20	40												11	38		63	4	1	2	
Senecio sp.3 (# 3931)					14	25	40	40																			
Dissanthelium calycinum		38	26	26	18	6	60		100	9													38	1			
Nototriche sp.1(# 3104)				5		13	40																				
Nototricho obcuneatae-Xenophylletum poposi Galán de Mera, Cáceres & Gonzáles 2003																											
Mniodes coarctata				16		88																			+	4	
Xenophyllum poposum						81				9															4		
Nototriche erinacea						56																					
Senecio trifurcifolius						31																					
Poa sp. (# 3099)						25																					
Nototriche sp.2 (# 4228a)						19																					
Senecio sp.4 (# 4228b)						13																					
Poo aequiglumae-Xenophylletum dactylophyllum																											
Nototriche sp.3 (# 2447)							100																				
Poa aequigluma							100																				
Poa spicigera							100														63						
Xenophyllum dactylophyllum							80																	1			
Community of *Senecio algens*																											
Senecio algens				2				80							2					17	13		13	1		1	
Senecio sp.5 (# 3942)								100																			
Class ¿?																											
Community of *Tarasa nototrichoides* and *Urtica flabellata*																											
Urtica flabellata									100																		
Lachemilla pinnata		38	4						100						1	+											
Tarasa nototrichoides		4	4						90																		
Perezia multiflora			17						50		13																
Solanum acaule									40			13															
Valeriana sp. (Image DSC075, 03/2014)									10																		
CRASSULETEA CONNATAE																											
Muhlenbergia peruviana		25	13	2								13	83														
Crassula connata		17																									
ARGYROCHOSMETEA NIVEAE; Salpichroetalia glandulosae																											
Asplenium peruvianum			9												4				71	11		100					
Belloa kunthiana				9																							
Belloa schultzii		4		2															29	6	38						
Loricaria graveolens			13																								
Salpichroa glandulosa				2	5											+			43	22		20					
Valeriana nivalis				9	5												2	1	14	94	25		13	2	+		
Companions																											
Calamagrostis curvula			17	44	36	56	100	80		39		13	100										13			4	+
Trisetum spicatum	40	33	4	2	36	19										+						20	38				
Luzula vulcanica		33	13	44	27	13																					
Parastrephia lucida			4	51	86	19	60			30															1	4	4
Pycnophyllum glomeratum		8	4	44	23	44	20																13		1	4	4
Microsteris gracilis	100	21	26		23																						
Paronychia andina		33	39	9	14																			3		3	
Senecio nutans			30		46	25	60			17	100		67													1	+
Stangea rhizanta	60			12	32			60														20	13				
Astragalus peruvianus		17	17	2																							
Bartsia diffusa		8	26	5						13							1			6			13				
Lepidium meyenii		13	9	5																				1			
Cardionema ramosissimum		8	4	2																							
Mniodes pulvinata				26	9	13																					
Poa candamoana	40			9	50						13	50	83	100													
Stipa ichu	60	29	78							26	38	75	100	20												1	
Astragalus uniflorus				7		6					13																
Chaetanthera peruviana			4		14							13															

# order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Geranium sessiliflorum			9	23								13		20		+						20		1		1	
Mancoa hispida		13	4																								
Adesmia spinosissima			9							22	13			20													
Cyperus seslerioides		13										13															
Descurainia athrocarpa				2																6			13	1			
Galium corymbosum			35									13				2			29	6		60					
Lupinus cuzcensis		4																									
Oxalis debilis			4																								
Oxalis nubigena			9																29					1			
Weberbauera peruviana			4																								
Species from other communities																											
Lupinus paruroensis										17	13		67														
Chersodoma jodopappa										4		13	33	20													
Deyeuxia heterophylla											25	13	67	20													
Deyeuxia breviaristata											13															+	3
Astragalus arequipensis											13																
Festuca rigescens											13												13			+	
Lupinus saxatilis											38			40													
Erigeron incarum											13		17														
Luzula racemosa										4													38	1			
Festuca dolichophylla												100	100	100					14				25				
Deyeuxia cabrerae													17							6	13		13		+	2	
Paranephelius ovatus												75	17	60										1			
Coreopsis fasciculata												75		60													
Plantago sericea												13	67														
Plantago linearis												25		20													
Nassella pubiflora												25	17														
Dissanthelinum macusaniense													17										25				
Nassella mucronata												38	83	60													
Trifolium amabile												63	17														
Bromus catharticus												38		20													
Lupinus microphyllus													17	20													
Senecio modestus															1	1						40	13				
Draba brackenridgei																+			29								
Mniodes andina																+					88						
Oxalis andina															1	+						60		1			
Senecio rhizomatus															1	+						20					
Cystopteris fragilis																+						20					
Asplenium triphyllum																1				11		40					
Senecio culcitioides																	1		14	28	13		50				
Woodsia montevidensis																		1	14								
Caiophora horrida																		1						1			
Sisymbium peruvianum																		1		6							
Stipa rigida																	1					20	63				
Xenophyllum ciliolatum																							25	2			
Silene andicola																							13	1	+	2	
Poa humilluma																							38	1			
Adesmia patancana																											1
Perezia ciliosa																											1

Other species: In 10 *Baccharis incarum* 57; in 10 *Nassella brachyphylla* 13, *Echinopsis pamparuizii* 9, *Baccharis genistelloides* 9, *Hypochaeris taraxacoides* 9, *Stipa nardoides* 4, *Stipa rigidiseta* 4, *Plantago monticola* 4, *Nassella asplundii* 4, *Polylepis tarapacana* 13, *Arenaria serpens* 9, *Dissanthelium peruvianum* 9, *Werneria* sp. 4, *Oxalis pachyrrhiza* 4, *Calamagrostis intermedia* 4, *Caiophora chuquitensis* 4, *Bomarea dulcis* 4, *Dissanthelinum breve* 4; in 11 *Stipa obtusa* 25, *Opuntia lagopus* 13, *Baccharis buxifolia* 13, *Adesmia miraflorensis* 13, *Polylepis rugulosa* 25, *Senecio adenophylloides* 13, *Senecio rudbeckiifolius* 13, *Stipa annua* 13; in 12 *Nassella pubiflora* 25, *Tunilla soehrensii* 13, *Quinchamalium procumbens* 13, *Echinopsis pampana* 13, *Vulpia megalura* 38, *Tagetes multiflora* 25, *Bidens pilosa* 25, *Gilia laciniata* 13, *Lepechinia meyenii* 13, *Nassella depauperata* 13, *Schkhuria multiflora* 13, *Chondrosum simplex* 13, *Hordeum muticum* 13, *Hypochaeris chillensis* 13, *Erodium cicutarium* 13, *Lepidium chichicara* 13; in 13 *Bartsia camporum* 50, *Mutisia arequipensis* 17, *Gnaphalium dombeyanum* 17; in 14 *Agrostis gelida* 100; in 16 *Asplenium castaneum* +, *Peperomia peruviana* 2, *Oxalis arenaria* 1; in 17 *Draba cryptantha* 2; in 18 *Gnaphalium* sp. 1, *Cerastium mucronatum* 1, *Phacelia pinnata* 1, *Lobivia caespitosa* 1; in 19 *Bomarea uniflora* 57, *Bowlesia sodiroana* 14, *Oxalis petrophila* 14, *Valeriana plectritoides* var. *pallida* 14, *Galium aparine* 14, *Poa horridula* 14; in 20 *Draba cuzcoensis* 6, *Ribes brachybothrys* 6; in 22 *Peperomia peruviana* 60, *Oxalis arenaria* 40, *Asplenium castaneum* 20, *Englerocharis peruviana* 20; in 23 *Xenophyllum decorum* 88, *Plettkea cryptantha* 38, *Xenophyllum digitatum* 13, *Chaetanthera cochlearifolia* 63, *Weberbauera rosulans* 13, *Niphogeton dissecta* 25, *Gentianella weberbaueri* 13, *Englerocharis peruviana* 50, *Nototriche aretioides* 38, *Nototriche pinnata* 13, *Plantago lamprophylla* 13, *Bromus villosissimus* 38, *Pycnophyllum weberbaueri* 13, *Pernettya prostrata* 13, *Niphogeton scabra* 13, *Astragalus brackenridgei* 13, *Deyeuxia tarmensis* 13, *Senecio tephrosioides* 13, *Deyeuxia ovata* 25, *Deyeuxia rigescens* 13, *Deyeuxia glacialis* 13, *Senecio canescens* 13, *Ephedra americana* 38, *Melpomene moliniformis* 13, *Valeriana candamoana* 38; in 24 *Poa gymnantha* 18, *Astragalus micranthellus* 1, *Bartsia crenata* 1, *Bromus lanatus* 1, *Chaetanthera boliviensis* 1, *Chaetanthera villosa* 1, *Deyeuxia cephalanta* 1, *Deyeuxia densiflora* 1, *Deyeuxia glaciaris* 1, *Gnaphalium badium* 1, *Niphogetom scabra* 1, *Poa aequigluma* 1, *Pycnophyllum filiforme* 1, *Senecio puchii* 1, *Valeriana interrupta* 1, *Viola nivalis* 1; in 25 *Deyeuxia deserticola* 9; in 26 *Nototriche* sp.

Appendix 1. Chasmophyte community distinguished in this vegetation survey and combining the *Saxifrago magellanicae-Leucherietum daucifoliae* (*Saxifragetalia magellanicae*).

Relevé #	1	2	3	4	5	PC
ALTITUDE	4590	4580	4580	4585	4590	
INCLINATION	20	25	18	5	5	
ORIENTATION	S	S	S	S	S	
# SPP	7	8	15	10	13	
VEGC %	20	20	25	25	25	
ROCKS %	0	5	5	5	5	
STONES %	50	55	50	30	40	
GRAZING (I-III)	0	0	0	1	1	
Argyrochosmetea niveae						
Saxifragetalia magellanicae, Saxifragion magellanicae						
Saxifraga magellanica	1	1	2	3	1	100
Saxifrago magellanicae-Leucherietum daucifoliae						
Leucheria daucifolia	1	2	2	1	3	100
Weberbauera sp. (# 3842)	.	1	1	1	.	60
Gentianella incurva	1	.	1	.	.	40
Perezia pinnatifida	.	.	1	1	.	40
Valeriana coarctata	.	.	1	.	1	40
Calamagrostietea vicunarum; Azorello-Festucion						
Descurainia depressa	.	.	1	1	1	60
Hypochaeris meyeniana	.	.	1	1	1	60
Weberbauera spathulifolia	.	1	1	.	2	60
Pycnophyllum molle	3	.	3	.	.	40
Chaetanthera stuebelii	.	.	1	.	.	20
Ephedra rupestris	.	.	.	.	1	20
Calamagrostietea vicunarum; Calamagrostion minimae						
Calandrinia acaulis	1		1	1	1	80
Anthochloo-Dielsiochloetea						
Anthochloa lepidula	.	1	.	.	1	40
Companions						
Microsteris gracilis	1	1	1	1	1	100
Stangea rhizanta	.	.	1	2	2	60
Stipa ichu	.	1	.	1	1	60
Poa candamoana	1	1	.	.	.	40
Trisetum spicatum	.	.	1	.	1	40

Sites: Rocky slopes of Yanahuara, Ichuña district.

Appendix 2. *Astragalo minimi-Azorelletum diapensioidis* with two subassociations distinguished in this vegetation survey at an altitude of 4460–4670 m.

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	PC
ALTITUDE	4580	4585	4590	4585	4590	4585	4585	4585	4590	4460	4520	4520	4530	4505	4545	4550	4551	4545	4500	4470	4550	4670	4635	4660	
INCLINATION	25	25	25	25	20	5	5	5	5	20	5	5	5	5	5	5	5	40	20	5	5	10	5	10	
ORIENTATION	S	S	S	S	S	N	N	N	N	S	E	SE	S	S	NW	NW	NW	SSW	W	W	NNW	S	S	S	
# SPP	14	13	14	16	17	18	20	20	20	18	20	24	21	19	22	20	18	19	17	22	20	17	17	17	
VEGC %	25	30	25	30	20	55	65	55	65	80	75	60	70	65	60	60	60	60	70	45	35	60	70	65	
ROCKS %	0	0	0	0	0	5	5	5	5	0	0	5	0	0	5	5	5	30	0	10	20	10	8	0	
STONES %	60	50	50	50	45	5	5	10	10	65	15	15	5	50	10	5	5	30	35	20	30	25	15	20	
GRAZING (I-III)	1	1	0	0	0	0	0	0	1	1	1	2	0	2	0	1	1	0	1	1	1	1	0	1	
MANURE (I-III)	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	
Calamagrostietea vicunarum																									
Calamagrostis vicunarum	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1	1	1	.	33
Parastrephietalia quadrangularis																									
Pycnophyllum molle	4	4	4	4	4	4	4	4	4	3	4	3	4	3	3	3	3	3	4	4	4	5	4	5	100
Tetraglochin cristatum	3	2	3	3	3	4	4	3	2	1	4	4	4	3	1	4	2	.	.	3	4	4	1	4	92
Nototriche anthemidifolia	.	1	.	1	.	1	2	.	.	2	2	2	2	3	.	.	2	.	1	.	.	1	2	1	58
Hypochaeris meyeniana	.	.	.	.	.	.	.	2	2	1	.	1	1	.	1	1	.	1	2	2	1	.	.	2	50
Brayopsis monimocalyx	.	.	.	.	.	1	2	1	1	.	.	.	2	2	.	2	.	2	.	1	1	.	.	2	46
Werneria pectinata	.	.	.	.	.	.	.	.	.	4	4	3	4	3	4	3	3	.	.	.	.	4	4	2	46
Belloa piptolepis	.	.	.	.	.	.	.	.	.	.	1	.	1	2	.	2	.	1	2	.	1	2	.	1	38
Werneria aretioides	.	.	.	.	.	.	.	.	.	1	1	.	1	.	1	1	1	1	.	2	2	.	.	.	38
Silene genovevae	.	.	.	.	.	.	.	.	.	.	1	1	2	2	1	1	1	.	.	.	.	.	.	1	33
Senecio spinosus	.	.	.	.	.	3	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.	1	2	2	29
Nototriche pedicularifolia	.	.	.	.	.	2	2	2	3	.	.	.	.	.	.	.	.	.	.	.	.	2	1	2	29
Erigeron rosulatus	.	1	.	.	1	.	1	.	1	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	25
Cerastium subspicatum	1	1	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	21
Draba macleanii	.	.	.	.	.	2	2	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
Hypochaeris eriolaena	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	13
Parastrephia quadrangularis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	4	4	.	.	.	13
Perezia coerulescens	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	13
Senecio humillimus	.	.	.	.	2	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	2	.	.	13
Wahlenbergia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	.	.	.	2	.	.	.	.	.	13
Conyza deserticola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	8
Descurainia depressa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	8
Ephedra rupestris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	3	.	.	8
Gomphrena meyeniana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	8
Lupinus ananeanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	.	.	8
Nototriche digitulifolia	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	8
Oxalis calachaccensis	.	.	.	.	.	.	.	.	.	.	.	2	.	1	.	.	.	.	.	.	.	.	.	.	8
Plantago sericea var. *lanuginosa*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	8
Sisyrinchium brevipes	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Senecio candollei	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	4
Spergularia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	4
Weberbauera spathulifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	4
Calamagrostion minimae																									
Oreomyrrhis andicola	.	.	2	3	.	1	.	1	.	.	2	.	1	.	2	3	.	.	.	.	.	1	.	2	42

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	PC
Calamagrostis minima	.	.	.	.	.	.	.	.	.	2	.	.	.	.	3	3	1	.	.	1	1	.	.	2	29
Werneria nubigena	.	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	17
Calandrinia acaulis	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	13
Astragalo minimi-Azorelletum diapensioidis																									
Astragalus minimus	4	3	4	4	4	4	4	4	4	2	2	2	2	.	4	1	2	.	2	2	1	.	2	.	83
Azorella diapensioides	2	.	1	2	2	4	4	2	.	.	2	2	.	2	2	.	3	4	.	2	.	2	.	2	67
Bougueria nubicola	.	.	.	1	1	2	1	1	1	.	.	2	2	.	2	2	.	2	.	1	2	1	1	2	67
Nototriche turritela	1	1	.	1	1	.	1	.	1	1	.	1	2	1	.	1	1	1	1	.	.	.	1	.	63
Werneria apiculata	.	.	.	.	.	2	2	2	2	2	2	3	.	.	.	2	2	.	2	2	2	.	2	2	58
Nototriche longirostris	1	.	2	1	.	2	1	2	.	.	.	.	.	.	3	2	.	.	.	.	.	.	.	3	38
wernerietosum melanandrae																									
Werneria melanandra	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38
Junellia minima	2	.	2	1	2	1	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29
aciachnetosum pulvinatae																									
Aciachne pulvinata	.	.	.	.	.	.	.	.	.	4	4	3	.	2	2	.	2	2	1	2	1	.	1	2	46
Ourisia muscosa	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	1	.	.	.	.	.	13
Viola hillii	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	4
Azorello-Festucion																									
Festuca orthophylla	2	2	3	2	3	.	4	4	4	4	.	4	.	3	4	2	.	2	.	.	.	2	.	.	63
Anthochloo-Dielsiochloetea																									
Dissanthelium calycinum	.	.	.	.	.	1	1	2	1	.	1	.	1	.	1	.	1	.	1	.	.	.	.	.	38
Anthochloa lepidula	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	2	.	.	.	.	.	.	.	13
Crassuletea connatae																									
Muhlenbergia peruviana	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	25
Crassula connata	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	2	.	1	.	.	.	.	1	.	17
Urticetea flabellatae																									
Lachemilla pinnata	1	1	1	.	1	.	.	.	.	2	.	.	.	.	3	3	.	1	.	.	.	.	2	.	38
Tarasa nototrichoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	4
Argyrochosmetea niveae																									
Belloa schultzii	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	4
Companions																									
Luzula vulcanica	.	1	1	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.	2	1	.	2	.	.	33
Paronychia andina	2	2	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	.	.	33
Trisetum spicatum	.	.	.	.	.	.	.	.	.	2	2	2	2	.	2	2	2	.	2	.	.	.	.	.	33
Stipa ichu	.	.	.	.	.	.	.	.	.	.	4	.	4	4	.	.	4	4	.	4	4	.	.	.	29
Microsteris gracilis	.	.	.	.	.	.	.	.	.	2	1	.	.	2	.	.	1	.	2	.	.	.	.	.	21
Astragalus peruvianus	1	2	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
Cyperus seslerioides	.	.	.	.	.	.	.	.	.	.	.	2	.	2	2	.	.	.	.	.	.	.	.	.	13
Lepidium meyenii	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	13
Mancoa hispida	.	.	.	.	.	.	.	.	.	.	.	2	.	3	2	.	.	.	.	.	.	.	.	.	13
Bartsia diffusa	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	8
Cardionema ramosissimum	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.	.	.	.	.	.	8
Pycnophyllum glomeratum	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	2	.	.	.	.	.	8
Lupinus cuzcensis	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4

Sites: 1-9, Puqa Saya, in the Ichuña district; 10-24, Ichuña district, near Cachilaya, Coriri, Jatun Puqio and Qhaqhaskinkri and the southern lower slopes of Pirhuani peak (Ubinas district).

Appendix 3. Grasslands and rocky slopes combining the *Astragalo pusillii-Parastrephietum quadrangularis* and three subassociations in the study sites of north of Moquegua at an altitude of 4450–4560 m.

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	PC
ALTITUDE	4450	4455	4450	4455	4450	4455	4500	4510	4560	4530	4540	4560	4550	4560	4510	4520	4520	4530	4540	4500	4500	4510	4500	
INCLIN	10	10	5	5	15	15	25	20	20	25	25	20	25	20	30	35	50	25	30	45	35	5	20	
ORIENT	NE	NE	NE	NE	E	E	N	N	N	N	N	N	N	N	SW	SSW	SSW	SW	NW	NW	NW	NW	W	
# SPS	10	10	8	10	14	6	13	16	15	11	16	13	15	17	22	19	19	18	13	22	17	20	16	
VEGC %	20	15	20	20	15	15	35	35	40	45	35	45	35	45	80	60	65	65	65	60	55	65	70	
ROCKS %	25	30	40	40	50	45	50	40	40	30	35	35	50	40	20	20	40	10	10	10	20	10	10	
STONES %	10	15	10	10	15	10	10	10	10	10	10	15	15	15	30	30	30	35	70	30	45	5	35	
GRAZING (I-III)	0	1	0	0	1	0	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	1	1	
MANURE (I-III)	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	1	1	0	1	0	1	1	
Calamagrostietea vicunarum																								
Calamagrostis vicunarum	1	.	1	1	.	1	.	.	1	.	.	1	1	1	1	.	1	1	.	.	.	.	2	52
Parastrephietalia quadrangularis																								
Hypochaeris meyeniana	.	1	.	1	.	1	1	1	.	.	2	.	1	.	2	2	2	2	3	2	2	2	2	70
Belloa piptolepis	.	.	.	.	.	.	.	1	1	1	1	.	1	1	2	2	2	2	2	1	1	1	2	65
Pycnophyllum molle	2	3	.	2	1	.	.	.	2	.	2	.	2	2	.	.	.	.	3	.	.	2	.	43
Tetraglochin cristatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	4	4	4	4	4	.	1	4	35
Lupinus ananeanus	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	2	3	2	2	.	26
Senecio spinosus	.	.	.	.	.	.	1	.	1	.	.	.	.	.	2	.	2	.	.	.	2	2	.	26
Weberbauera spathulifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	.	.	1	1	2	.	26
Cerastium subspicatum	1	1	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22
Nototriche digitulifolia	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22
Senecio humillimus	.	.	.	.	2	.	.	2	.	.	.	2	.	.	.	2	.	.	.	.	.	2	.	22
Silene genovevae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	3	.	.	1	2	.	22
Senecio candollei	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
Wahlenbergia peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	4	17
Werneria pectinata	.	.	.	.	.	.	.	1	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	17
Descurainia depressa	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1	.	.	13
Perezia coerulescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	2	.	.	.	.	.	13
Plantago sericea var. *lanuginosa*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	13
Conyza deserticola	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	9
Ephedra rupestris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	.	.	9
Lobivia maximiliana	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	9
Brayopsis monimocalyx	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Senecio tassaensis	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Azorello-Festucion																								
Azorella compacta	.	.	2	.	2	.	2	3	3	3	3	3	2	2	5	5	5	5	4	4	4	5	.	78
Festuca orthophylla	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	2	4	4	.	22
Baccharis caespitosa	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13
Belloa sp. (#3945)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	.	1	.	17
Bowlesia tropaeolifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	4
Cumulopuntia boliviana subsp. *ignescens*	.	.	.	.	.	.	.	3	.	3	.	2	.	.	.	.	.	.	.	.	3	.	3	22
Astragalo pusillii-Parastrephietum quadrangularis																								
Parastrephia quadrangularis	.	1	2	.	1	.	3	1	1	1	2	.	2	1	2	3	2	3	3	4	2	4	4	83
Astragalus pusillus	.	.	1	1	1	.	.	1	.	.	1	2	.	.	2	.	2	2	2	2	2	3	2	65
sisyrinchietosum trinervis																								
Sisyrinchium trinervis	1	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
baccharidetosum tricuneatae																								
Baccharis tricuneata	.	.	.	.	.	.	2	2	1	2	1	2	4	2	.	.	.	.	.	.	.	.	.	35
Descurainia sp. (#0940)	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	PC
Junellia sp. (#4019)	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	4
Valeriana aschersoniana	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	4
astragaletosum pusillii																								
Sisyrinchium brevipes	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	2	2	.	.	1	.	.	.	22
Conyza sp. (#2601)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	2	.	.	17
Calamagrostion minimae																								
Azorella diapensioides	.	.	.	.	.	.	.	.	2	.	.	.	.	2	.	.	.	.	.	.	.	.	.	9
Astragalus minimus	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.	1	.	1	.	2	.	2	.	26
Bougueria nubicola	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	1	.	2	.	17
Werneria apiculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	4
Nototriche longirostris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	13
Aciachne pulvinata	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Anthochloo-Dielsiochloetea																								
Dissanthelium calycinum	.	.	.	.	.	.	.	.	1	.	1	.	.	1	.	.	.	.	2	1	.	.	1	26
Urticetea flabellatae																								
Lachemilla pinnata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	4
Tarasa nototrichoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	4
Perezia multiflora	.	.	.	.	.	.	.	.	.	1	.	.	1	1	.	.	.	.	.	1	.	.	.	17
Crassuletea connatae																								
Muhlenbergia peruviana	.	.	.	.	.	.	1	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	13
Argyrochosmetea niveae																								
Asplenium peruvianum	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	9
Loricaria graveolens	2	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13
Companions																								
Senecio nutans	.	.	.	.	2	.	2	.	.	.	2	1	.	3	.	.	.	2	.	2	.	.	.	30
Stipa ichu	1	.	1	2	.	2	3	3	4	2	2	4	2	4	3	3	2	3	.	3	.	.	4	78
Paronychia andina	1	1	.	1	1	.	1	1	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	39
Galium corymbosum	.	.	.	.	.	.	.	1	.	1	.	1	1	1	.	1	1	1	.	.	.	.	.	35
Astragalus peruvianus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	2	.	.	.	.	.	17
Bartsia diffusa	.	.	.	.	.	.	.	.	1	.	.	1	1	1	.	.	.	.	.	1	.	.	1	26
Microsteris gracilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	1	.	.	2	1	2	26
Calamagrostis curvula	1	1	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	17
Luzula vulcanica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	.	.	.	.	.	2	13
Adesmia spinosissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	9
Geranium sessiliflorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.	9
Lepidium meyenii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	9
Oxalis nubigena	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	9
Belloa longifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	4
Cardionema ramosissimum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	4
Chaetanthera peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	4
Mancoa hispida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	4
Oxalis debilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	4
Parastrephia lucida	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Pycnophyllum glomeratum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	4
Trisetum spicatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	4
Weberbauera peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	4

Sites: 1-6, the Rancho-Pirhuani area, near Tassa locality in the Ubinas district; 7-14, the road between Carmen Chaclaya and Matazo sites in the Ubinas district; 15-23, Coriri and Qhaqhaskinkri sites in the Ichuña district.

Appendix 4. *Senecioni moqueguensis-Pycnophylletum molle* and four subassociations in the study sites of North Moqueguа at an altitude of 4500–4735 m.

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	PC
ALTITUDE	4500	4578	4545	4523	4610	4630	4670	4660	4680	4680	4690	4677	4690	4516	4610	4640	4610	4610	4680	4690	4690	4690	4690	4690	4695	4700	4700	4590	4600	4590	4590	4680	4680	4590	4590	4595	4570	4570	4580	4580	4590	4590	4590	
INCLIN	10	15	15	10	5	15	10	10	45	25	25	20	20	15	10	5	5	5	5	5	5	5	5	5	5	5	5	5	10	10	10	10	5	5	5	10	10	15	15	10	10	10	10	
ORIENT	W	W	W	E	W	NNW	SW	N	NE	N	NE	N	N	E	W	S	W	W	SE	SE	SE	SE	SE	SE	SE	SE	SE	S	N	E	E	E	SE	S	S	S	S	S	S	N	N	N	N	
#SPS	22	27	25	21	14	17	18	15	22	23	22	21	25	21	14	15	12	12	13	12	13	12	14	11	14	12	11	12	17	13	14	15	6	10	10	17	17	19	19	16	20	17	20	
VEGC %	50	70	70	65	30	50	50	30	65	55	65	70	70	70	35	65	30	30	45	40	45	40	40	45	40	35	30	70	65	40	45	40	35	65	70	75	45	30	35	30	35	35	35	
ROCKS %	5	15	35	40	10	15	0	4	40	0	30	20	0	10	15	10	20	20	6	6	8	8	10	8	8	10	10	5	7	20	15	15	10	7	9	10	35	10	15	5	5	12	25	
STONES %	25	30	25	30	40	30	35	16	35	6	20	30	50	30	28	30	35	35	30	30	25	25	20	20	25	18	17	20	35	35	30	35	30	20	35	50	20	25	10	35	30	30	20	
GRAZING (I-III)	1	0	1	1	0	1	1	0	0	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	
MANURE (I-III)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	
Calamagrostietea vicunarum																																												
Calamagrostis vicunarum	1	2	2	.	2	1	.	1	1	.	.	2	.	1	1	1	2	2	1	.	1	1	.	1	.	2	.	.	.	.	.	.	.	.	.	.	1	1	2	.	1	1	.	53
Parastrephietalia quadrangularis																																												
Pycnophyllum molle	4	4	4	4	4	4	5	4	.	3	4	4	4	4	4	4	4	4	3	3	3	3	4	4	3	4	4	2	3	2	3	2	3	3	3	.	2	2	4	4	4	2	.	93
Belloa piptolepis	1	1	1	1	1	.	1	1	1	2	2	1	3	1	1	1	2	2	1	1	.	.	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	51
Nototriche anthemidifolia	1	.	.	1	.	1	2	2	.	1	1	.	.	.	.	.	1	.	.	1	.	2	1	.	1	.	1	1	1	.	.	.	.	.	1	.	.	1	.	1	1	1	1	49
Chaetanthera stuebelii	.	.	1	.	.	1	1	1	.	.	1	.	.	1	.	1	.	1	.	1	.	.	1	.	1	.	1	.	.	.	.	1	.	.	1	.	1	.	1	1	1	.	1	44
Werneria aretioides	1	.	.	.	.	.	.	2	.	.	.	.	.	1	2	2	2	2	1	1	2	.	1	1	.	2	3	1	1	.	.	.	2	.	.	2	.	.	.	.	.	.	.	42
Erigeron rosulatus	1	1	.	1	.	1	.	.	.	1	1	.	1	.	.	.	.	.	1	1	.	1	.	1	1	1	1	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	37
Senecio candollei	2	1	2	.	.	.	.	.	3	1	4	4	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	1	1	.	.	1	.	1	.	2	37
Brayopsis monimocalyx	1	.	.	.	.	1	.	.	.	.	2	.	2	.	.	.	.	.	1	.	1	.	1	.	1	2	.	.	.	.	.	.	.	.	.	.	1	.	1	.	1	1	1	33
Hypochaeris meyeniana	.	2	.	2	.	.	.	1	2	2	.	3	3	.	1	1	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	1	1	.	.	.	.	.	.	.	30
Draba macleanii	.	1	.	.	.	.	.	.	1	.	1	1	1	.	.	.	.	.	1	1	.	1	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28
Ephedra rupestris	1	2	2	.	.	.	.	.	3	.	.	3	2	1	.	.	.	.	2	.	.	1	.	2	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26
Werneria pectinata	.	1	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	2	2	1	1	23
Nototriche pedicularifolia	.	.	.	.	.	.	.	.	2	3	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	16
Weberbauera spathulifolia	.	.	.	.	1	1	.	.	3	4	3	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16
Senecio humillimus	2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	2	1	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Tetraglochin cristatum	2	3	.	2	.	.	.	.	.	.	.	.	.	1	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Hypochaeris eriolaena	.	1	1	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12
Perezia coerulescens	.	.	2	.	.	.	.	.	2	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Senecio spinosus	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	9
Descurainia depressa	.	.	.	.	.	.	1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Silene genovevae	.	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Cerastium subspicatum	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Lupinus ananeanus	.	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Nototriche digitulifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	5
Parastrephia quadrangularis	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Azorello-Festucion																																												
Azorella compacta	4	5	4	4	4	4	.	4	5	4	5	5	5	4	.	3	.	3	.	2	.	3	.	.	3	.	3	.	4	4	4	3	3	4	.	4	3	.	3	4	4	3	4	74
Festuca orthophylla	4	4	4	4	4	4	4	2	2	3	.	3	2	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	2	2	.	.	.	2	1	2	2	.	.	2	.	51
Baccharis tricuneata	4	4	.	3	.	1	.	2	.	3	3	2	.	2	.	.	.	.	.	.	1	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	2	33
Stangea wandae	2	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	16
Baccharis caespitosa	4	3	2	.	.	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12
Bartsia elongata	.	.	.	.	.	.	.	.	1	1	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Caiophora rosulata	.	.	.	.	.	.	.	.	.	1	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Werneria glaberrima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	1	2	.	.	.	.	.	.	.	9
Belloa sp. (#3945)	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Bowlesia ttropaeolifolia	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Senecio evacoides	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Bartsia sp. (#3092)	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Senecioni moqueguensis-Pycnophylletum molle																																												
Senecio moqueguensis	2	2	1	1	1	1	2	1	2	1	2	1	1	2	1	2	1	2	1	1	2	2	1	1	1	.	1	.	.	1	.	.	2	.	.	1	2	3	2	3	2	2	2	84
Nototriche argentea	.	.	.	.	1	.	.	.	3	.	2	4	2	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
Perezia coerulescens var. *amplibr*	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	9
Senecio sp.1 (#4217a)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	7
mniodetosum pulvinatae																																												
Mniodes pulvinata	3	2	2	2	3	3	2	.	3	.	3	3	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26
Myrosmodes sp. (#2287)	.	.	.	.	.	.	.	.	.	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Lupinus sp. (#2424)	.	.	.	.	.	.	.	.	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Senecio bolivarianus	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	PC
senecionetosum tassaensis																																												
Senecio tassaensis	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	1	.	1	1	.	1	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26
Xenophyllum weddellii	1	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Oritrophium sp. (#2194b)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	12
Werneria heteroloba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
gentianelletosum primuloides																																												
Gentianella primuloides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	.	.	.	.	.	.	.	16
Senecio graveolens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	7
Xenophyllum digitatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	5
Viola sp. (#4217a)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	5
arenarietosum acaulis																																												
Arenaria acaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	16
Nototriche sepaliloba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	16
Cerastium behmianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	1	1	14
Nototriche pusilla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	1	.	12
Senecio sykorae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	.	1	12
Poa brevis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	1	7
Spergularia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	7
Werneria sp. (#3940)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	5
Parastrephietalia quadrangularis; Calamagrostion minimae																																												
Calandrinia acaulis	.	.	.	.	.	.	.	.	1	.	.	.	2	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	19
Crassuletea connatae																																												
Muhlenbergia peruviana	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Anthochloo-Dielsiochloetea																																												
Anthochloa lepidula	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	5
Senecio rufescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	5
Dissanthelium calycinum	.	.	1	1	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	2	.	.	.	.	.	.	.	.	.	1	1	.	1	1	.	1	26
Nototriche sp.1 (#3104)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	5
Mniodes coarctata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	2	.	2	2	2	.	2	16
Senecio algens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	2
Salpichroetalia glandulosae; Argyrochosmetea niveae																																												
Belloa kunthiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	1	.	.	.	1	.	9
Valeriana nivalis	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	.	.	.	.	.	.	.	.	.	.	.	9
Belloa schultzii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Salpichroa glandulosa	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Companions																																												
Parastrephia lucida	.	4	3	4	3	3	3	3	4	4	4	4	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	.	.	.	.	3	2	2	2	2	2	2	51
Luzula vulcanica	1	2	2	2	1	.	.	.	3	1	2	.	2	1	1	1	.	.	.	.	1	.	1	.	1	.	.	1	1	.	.	.	.	.	1	1	.	.	.	.	.	.	.	44
Calamagrostis curvula	.	1	1	1	1	1	.	.	.	.	.	.	.	2	2	1	.	.	1	1	1	.	1	1	1	1	1	.	.	2	2	1	.	.	.	.	.	.	.	.	.	.	.	44
Pycnophyllum glomeratum	.	.	.	.	2	3	.	.	.	3	3	2	.	.	.	4	2	2	2	.	2	2	.	.	2	3	.	2	2	1	1	1	.	1	.	.	.	.	.	.	.	.	.	44
Geranium sessiliflorum	.	.	1	2	.	.	.	.	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	1	1	.	1	1	.	23
Stangea rhizanta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	1	1	.	.	.	.	.	.	.	12
Poa candamoana	.	.	.	.	.	.	.	.	1	2	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Paronychia andina	2	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	9
Astragalus uniflorus	2	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Dielsiochloa floribunda	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Bartsia diffusa	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Bougueria nubicola	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Lepidium meyenii	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Perezia pinnatifida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	5
Astragalus minimus	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Astragalus peruvianus	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Cardionema ramosissimum	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Descurainia athrocarpa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Trisetum spicatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2
Valeriana coarctata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	2

Sites: 1-13, Gasawasi-Witopata site, the northern lower slopes of Pirhuani peak, the extensive plateaus surrounding the group of lakes upslope Coalaque and Querala localities (Ubinas district) and the Choco-Choco lower mountain slopes in Yunga district; 14-29, northern plateaus of the Ubinas district; 30-36, extensive plateaus of the Yunga district; 37-43, Condor Sallana environs close to Matazo locality (Ubinas

Appendix 5. *Calamagrostio trichophyllae-Azorelletum compactae* and two subassociations in the study sites of North Moquegua at an altitude of 4590–4800 m.

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	PC
ALTITUDE	4715	4720	4715	4715	4720	4735	4715	4720	4795	4800	4795	4795	4795	4800	4800	4620	4665	4665	4665	4590	4665	4665	
INCLIN	45	90	45	45	90	5	45	5	30	10	30	30	30	10	10	15	10	10	10	25	10	10	
ORIENT	NW	NW	NW	NW	NW	N	NW	N	N	W	N	N	N	W	W	NNW	E	E	E	S	E	E	
# SPS	15	13	17	14	17	11	12	13	19	19	20	16	16	16	15	22	27	25	20	22	22	26	
VEGC %	45	45	45	40	45	35	55	50	50	35	35	55	60	40	35	60	30	50	55	45	50	60	
ROCKS %	10	70	10	10	80	10	10	5	15	30	10	20	15	20	30	10	0	14	18	10	10	18	
STONES %	10	10	10	20	10	85	85	25	5	55	10	15	5	40	45	35	40	20	25	25	25	20	
GRAZING (I-III)	0	1	0	0	1	0	1	1	0	0	1	1	0	0	0	1	1	0	0	0	0	0	
MANURE (I-III)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	
Calamagrostietea vicunarum																							
Calamagrostis vicunarum	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	1	.	.	.	.	1	.	18
Parastrephietalia quadrangularis																							
Pycnophyllum molle	.	.	.	.	.	4	4	4	2	2	2	.	2	4	4	4	4	4	4	.	2	4	68
Nototriche anthemidifolia	.	.	1	1	.	.	1	1	.	.	1	1	1	1	1	.	2	1	1	.	1	2	64
Ephedra rupestris	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	.	2	2	.	32
Belloa piptolepis	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2	4	1	1	.	.	1	.	32
Brayopsis monimocalyx	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	1	.	.	1	23
Chaetanthera stuebelii	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	.	1	.	23
Plantago sericea var. *lanuginosa*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	1	23
Weberbauera spathulifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	1	.	.	1	18
Senecio humillimus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	2	18
Draba macleanii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	.	18
Erigeron rosulatus	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	1	.	.	1	.	18
Hypochaeris meyeniana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	1	14
Senecio candollei	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	5
Nototriche argentea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	5
Azorello-Festucion																							
Azorella compacta	4	4	.	4	4	4	4	.	4	4	4	4	4	4	.	.	4	4	4	4	.	4	77
Festuca orthophylla	4	2	3	3	1	.	.	.	.	.	3	4	.	.	.	2	2	2	.	.	.	.	46
Baccharis tricuneata	.	.	.	.	.	.	.	.	2	.	2	2	4	2	2	3	2	2	.	2	.	.	46
Baccharis caespitosa	.	.	.	.	.	.	.	.	2	.	2	.	.	.	2	1	1	.	.	1	1	1	36
Senecio evacoides	2	2	2	.	2	2	.	2	.	.	.	.	.	2	.	.	.	.	.	.	.	.	32
Belloa sp. (# 3945)	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	1	1	.	.	.	1	27
Stangea wandae	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	1	.	1	.	.	1	27
Bowlesia tropaeolifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	1	18
Caiophora rosulata	1	3	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
Cumulopuntia boliviana subsp. *ig*	.	.	3	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Bartsia elongata	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	14

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	<u>14</u>	15	16	17	18	19	<u>20</u>	21	22	PC
Calamagrostio trichophyllae-Azorelletum compactae																							
Calamagrostis trichophylla	1	.	1	1	2	.	2	1	1	.	1	1	2	1	1	2	.	2	2	1	.	1	77
Nototriche mandoniana	1	1	1	1	.	1	.	1	1	1	1	.	1	1	1	1	1	2	1	.	1	.	77
Silene mandonii	1	1	1	1	1	1	.	1	.	1	1	1	1	.	.	.	1	1	.	1	1	.	68
Perezia pungens	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	1	.	1	1	1	1	36
mniodetosum pickeringii																							
Mniodes pickeringii	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	.	.	.	.	.	.	.	68
Senecio sp.2 (#3935)	1	3	2	1	2	3	1	3	3	4	2	4	2	2	.	.	.	.	.	.	.	.	64
Erigeron lanceolatus	1	3	1	2	2	2	2	3	1	1	.	.	.	.	.	.	.	.	.	.	.	.	46
Werneria glaberrima	1	2	1	.	3	2	2	3	2	2	.	.	.	.	.	.	.	.	.	.	.	.	41
Nototriche pedatiloba	1	.	.	1	1	.	1	1	.	1	.	1	.	.	1	.	.	.	.	.	.	.	36
drabetosum soratensis																							
Draba soratensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	1	1	1	2	32
Bartsia sp. (#3092)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	1	.	18
Poa gilgiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	18
Agrostis breviculmis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	1	14
Lupinus chilensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	5
Viola granulosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	14
Anthochloo-Dielsiochloetea																							
Anthochloa lepidula	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	9
Dissanthelium calycinum	.	.	.	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
Senecio rufescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	2	14
Senecio sp.3 (#3931)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	14
Argyrochosmetea niveae																							
Salpichroa glandulosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	5
Valeriana nivalis	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	5
Companions																							
Parastrephia lucida	4	3	4	4	3	4	3	2	2	2	2	.	.	2	2	2	2	2	3	2	.	3	86
Poa candamoana	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	1	1	1	1	1	2	2	50
Senecio nutans	.	.	2	.	3	.	.	.	1	2	.	1	2	1	2	1	1	.	.	.	.	.	46
Calamagrostis curvula	1	1	1	.	1	.	2	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	36
Trisetum spicatum	.	.	2	2	3	.	.	.	.	.	.	.	.	.	.	.	2	1	.	2	2	1	36
Stangea rhizanta	.	.	1	.	2	.	.	.	2	2	1	1	1	.	.	.	.	.	.	.	.	.	32
Luzula vulcanica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	1	1	.	27
Microsteris gracilis	.	.	.	.	.	.	.	.	1	1	1	1	1	.	.	.	.	.	.	.	.	.	23
Pycnophyllum glomeratum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	2	2	.	2	23
Chaetanthera peruviana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	14
Paronychia andina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2	.	2	.	14
Mniodes pulvinata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	9
Sites: 1-15, lower slopes of the Choco-Choco Mountain (Yunga district); 16-22, summits and slopes of the mountains north of the Ichuña locality in the Yanapuquio site (Ichuña district)																							

Appendix 6. *Nototricho obcuneatae-Xenophylletum poposi* Galán de Mera, Cáceres & Gonzáles 2003 and two subassociations at an altitude of 4650–4735 m.

Relevé #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	PC
ALTITUDE	4660	4650	4650	4650	4650	4650	4650	4650	4660	4730	4735	4705	4700	4710	4710	4700	
INCLIN	5	5	5	10	5	5	5	5	5	10	5	5	5	10	5	10	
ORIENT	NNW	SSE	SSE	W	NNW	SSE	NNW	SSE	NNW	S	N	SE	SE	SE	SE	SE	
# SPS	17	9	10	9	6	8	6	8	7	7	10	8	7	8	5	6	
VEGC %	45	30	20	40	40	30	30	35	35	20	25	10	10	15	10	15	
ROCKS %	0	0	0	10	0	0	0	0	10	9	10	0	5	5	0	0	
STONES %	25	40	30	25	30	30	30	20	35	86	75	100	90	90	80	90	
GRAZING (I-III)	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	
MANURE (I-III)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
Anthochloo-Dielsiochloetea																	
Anthochloa lepidula	1	1	1	1	1	1	.	1	1	1	1	1	1	1	1	1	94
Dielsiochloa floribunda	.	.	1	.	.	.	.	.	.	1	1	.	1	.	1	.	31
Nototrichion obcuneatae																	
Senecio rufescens	2	2	3	4	.	2	4	3	.	2	2	.	.	.	.	.	56
Senecio sp.3 (#3931)	2	.	.	.	.	1	.	.	.	2	.	.	.	1	.	.	25
Nototriche sp.1 (#3104)	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	13
Dissanthelium calycinum	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	6
Nototriche obcuneata	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	6
Nototricho obcuneatae-Xenophylletum poposi Galán de Mera, Cáceres & Gonzáles 2003																	
Xenophyllum poposum	2	2	1	1	1	3	.	2	.	.	3	2	1	2	1	2	81
Mniodes coarctata	.	3	4	2	4	3	3	4	.	3	4	2	2	2	2	2	88
nototrichietosum erinaceae																	
Nototriche erinacea	1	.	1	2	.	2	1	1	1	1	1	.	.	.	.	.	56
Poa sp. (#3099)	1	.	.	1	1	.	.	1	.	.	.	.	.	.	.	.	25
Nototriche sp.2 (#4228a)	3	.	.	.	.	.	2	.	2	.	.	.	.	.	.	.	19
senecionetosum trifurcifolii																	
Senecio trifurcifolius	.	.	.	.	.	.	.	.	.	.	.	1	1	2	1	1	31
Senecio sp.4 (#4228b)	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	13
Parastrephietalia quadrangularis																	
Pycnophyllum molle	4	4	4	.	4	4	.	.	4	.	.	.	.	.	.	.	38
Azorella compacta	.	.	.	.	.	.	.	.	.	.	4	2	.	.	.	.	13
Senecio tassaensis	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	13
Mniodes pickeringii	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	6
Belloa piptolepis	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Werneria pectinata	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Companions																	
Calamagrostis curvula	1	1	1	.	.	1	.	1	1	2	.	1	.	.	.	1	56
Pycnophyllum glomeratum	4	4	4	4	.	.	4	4	4	.	.	.	.	.	.	.	44
Senecio nutans	2	.	2	2	2	.	.	.	.	.	.	.	.	.	.	.	25
Trisetum spicatum	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	2	19
Parastrephia lucida	4	4	.	.	.	.	.	.	.	.	2	.	.	.	.	.	19
Luzula vulcanica	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	13
Mniodes pulvinata	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	13
Astragalus uniflorus	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6

Sites: 1-11, extensive plateaus of the Pirhuani peak (Ubinas district) and the lower mountain peaks of Choco-Choco (Yunga district); 12-16, Janchata lower slopes (Carumas district).

Appendix 7. *Poo aequiglumae-Xenophylletum dactylophyllum* in the study sites in the north of Moquegua at an altitude of 4780–4795 m.

Relevé #	1	2	3	4	5	PC
ALTITUDE	4795	4790	4795	4785	4780	
INCLIN	30	15	15	15	15	
ORIENT	SSW	SSW	SSW	SSW	SSW	
# SPS	8	14	9	10	8	
VEGC %	20	15	15	15	20	
ROCKS %	15	8	8	8	5	
STONES %	10	34	30	38	40	
GRAZING (I-III)	0	0	0	0	0	
MANURE (I-III)	0	0	0	0	0	
Anthochloo-Dielsiochloetea						
Anthochloa lepidula	.	1	1	1	1	80
Dielsiochloa floribunda	1	1	1	.	.	60
Nototrichion obcuneatae						
Dissanthelium calycinum	1	1	.	1	.	60
Nototriche obcuneata	.	1	1	.	1	60
Senecio rufescens	1	.	.	.	.	20
Nototriche sp.1 (# 3104)	.	1	.	1	.	40
Senecio sp.3 (# 3931)	.	1	.	1	.	40
Poo aequiglumae-Xenophylletum dactylophyllum						
Xenophyllum dactylophyllum	.	3	4	3	4	80
Nototriche sp.3 (# 2447)	1	1	1	1	1	100
Poa aequigluma	1	2	1	1	1	100
Poa spicigera	1	1	1	1	1	100
Companions						
Calamagrostis curvula	1	1	1	1	1	100
Parastrephia lucida	2	2	.	.	2	60
Senecio nutans	.	2	2	2	.	60
Pycnophyllum glomeratum	.	2	.	.	.	20

Sites: 1-5, Choco-Choco rocky slopes (Yunga district).

Appendix 8. Community of *Senecio algens* occurring at an altitude of 4740–4760 m.

Relevé #	1	2	3	4	5	PC
ALTITUDE	4750	4745	4750	4740	4760	
INCLIN	35	45	35	35	35	
ORIENT	W	NW	W	W	W	
# SPS	5	6	5	5	5	
VEGC %	6	5	4	4	4	
ROCKS %	0	8	0	0	0	
STONES %	90	90	90	90	90	
GRAZING (I-III)	0	1	0	0	0	
MANURE (I-III)	0	0	0	0	0	
Anthochloo-Dielsiochloetea						
Dielsiochloa floribunda	1	.	1	1	.	60
Anthochloa lepidula	.	1	.	.	1	40
Nototrichion obcuneatae						
Senecio rufescens	.	1	.	.	1	40
Senecio sp.3 (# 3931)	.	.	.	1	1	40
Nototriche obcuneata	.	.	.	.	2	20
Community of *Senecio algens*						
Senecio algens	1	1	1	1	.	80
Senecio sp.5 (# 3942)	2	3	2	2	4	100
Companions						
Calamagrostis curvula	1	1	1	1	.	80
Stangea rhizanta	1	1	1	.	.	60

Sites: 1-5, Choco-Choco rocky slopes (Yunga district).

Appendix 9. Community of *Tarasa nototrichoides* and *Urtica flabellata* distributed between 4460 and 4650 in North Moquegua (South Peru).

	1	2	3	4	5	6	7	8	9	10	PC
ALTITUDE	4550	4550	4550	4650	4650	4460	4460	4460	4460	4590	
INCLIN	0	0	0	0	0	0	0	0	0	0	
ORIENT	-	-	-	-	-	-	-	-	-	-	
# SPS	4	4	5	5	5	4	6	6	5	5	
VEGC %	100	90	100	80	90	90	100	80	80	90	
STONES %	0	0	4	0	4	0	4	0	0	0	
GRAZING (I-III)	0	0	0	0	0	0	0	0	0	1	
MANURE (I-III)	3	3	3	3	3	3	3	3	3	3	
Community of *Tarasa nototrichoides* and *Urtica flabellata*											
Urtica flabellata	4	3	3	3	3	3	4	3	4	3	100
Lachemilla pinnata	1	1	1	1	1	1	1	1	2	2	100
Tarasa nototrichoides	1	2	1	2	3	.	2	2	1	2	90
Perezia multiflora	.	.	1	1	1	.	1	1	.	.	50
Solanum acaule	.	.	.	.	.	1	2	1	2	.	40
Valeriana sp. (Image DSC075, 03/2014)	.	.	.	.	.	.	.	.	.	4	10
Anthochloo-Dielsiochloetea											
Dissanthelium calycinum	1	1	1	1	1	1	1	1	1	1	100

Sites: Districts of Yunga, Ubinas and Ichuña.

CHAPTER 6

Phytogeography of the vascular high mountain flora genera of North Moquegua (Southern Peru)

Montesinos, D.B., Sýkora, K.V., Cleef, A.M. & Berendse, F.

Abstract

The mountains of North Moquegua are located in the Central Andes and their flora is composed of genera that are distributed over both tropical and temperate areas. The aim of this study is to analyse the geographical distribution, the diversity and the degree of endemism of the flora of the high mountains in Moquegua, South Peru. Of the total of 257 genera listed, more than 45% are predominantly distributed in tropical regions, less than 40% are distributed in temperate regions and 7% are considered to be cosmopolitan. The mountains of North Moquegua (South Peru) are divided into three major vegetation zones: prepuna (3400–3800 m), puna (3800–4500 m) and superpuna (4500–4800 m).

More than 45% of the genera represent Andean elements. Most of these genera are restricted to the central-southern Andes. This suggests that the Moquegua-related and Andean genera have considerable levels of speciation in these valleys. Many genera and more than half of the species have their northernmost distribution in South Peru (Central Andes), thereby underlining strong relationships with southern South America (North Chile and NW Argentina), but accentuating weaker relations with the puna-páramo elements. Of all the generic floras, North Moquegua is most similar to the North of Chile and Northwest Argentina. Colombia and Ecuador are highly related and form a separate group. The Bolivian Andean flora is very similar to the Cusco flora (S Peru) and to the more distant Cajamarca flora (N Peru). Junín and Ancash are grouped together and at a higher level linked to Bolivia and Cusco.

The data support the existence of a floristic transition zone in dry to arid environments in central-southern Peru which separates a tropical dry flora to the north from a dry subtropical/warm temperate flora to the south. Although the proportion of elements differs among prepuna, puna and superpuna, their composition does not differ significantly from that of the entire Andean flora.

The temperate component also accounts for a considerable proportion (37%) of the list of genera. It comprises genera with a wide area in both hemispheres, Holarctic genera with their main area in the northern hemisphere, Austral-Antarctic genera with a mainly subantarctic area, and an antitropic element mainly consisting of species with a subtropic, disjunct area occurring in both hemispheres just outside the tropical zone. Finally, the proportion (15%) of cosmopolitan genera is significant.

Moisture (precipitation) is the main driver of the phytogeographical regions. The updated and revised phytogeography provides an important contribution to our knowledge of the spatial distribution of biodiversity in the Andes and will help planners to identify regions of high conservation relevance.

Key words
Moquegua, Peru, Andes, endemism, altitude, species richness, biodiversity.

Introduction

With approximately 15,000 to 25,000 species of vascular plants, including about 5520 endemics, plant species diversity in Peru is extremely high (Brako & Zarucchi 1993; León et al. 2006; Convention on Biological Diversity 2014). Part of this floristic richness is attributable to Peru´s size, extending from subequatorial to tropical latitudes ca. 22° south). Moreover, Peru is extremely varied in physiography, with altitudes ranging from sea level to 7000 m in the Andes. The size and relief of Peru makes it one of the most biogeographically diverse countries of South America.

The Andean regions in North Moquegua exhibit great environmental variation in climate at regional and local scales. They are more humid than the southern regions and their precipitation is comparable with the average in the Lake Titicaca region. Sklenář & Balslev (2007) suggest that the climatic conditions impose very strong selection pressures on plants, which must cope with large diurnal changes in temperature and humidity, often involving both frost and frost-free environments.

Understanding how these mountain floras evolved is important since it can provide general insights into the origins of plant species diversity (Van der Hammen & Cleef 1986; Kitayama 1996; Winkworth et al. 2005). At a continental scale aseasonal humid conditions in the equatorial Andes change to seasonal, warm-cool and dry-humid altiplano at midlatitudes and seasonal, cool, humid temperate Andes further south (Cabrera, 1968; Simpson, 1983; Troll 1968). This latitudinal gradient is accompanied by pronounced floristic differences, which has led to the delimitation of major phytogeographical units of the high Andes, such as páramo, jalca, and puna (Sklenář & Balslev 2007). Simpson (1983) stated that as the Andes rose, the uplift produced a disparity in climatic conditions from north to south along the Andes and from low to high elevations within particular latitudes.

Rivas-Martínez & Tovar (1983) presented a synthesis of the biogeographical regions of the Andes comprising the Andean subkingdom, which includes the páramo, the puna (the focus of this study), the Pacific desert and Patagonia. For the Peruvian highlands, Kuentz et al. (2007) recognise three altitudinal zones called lower, upper and puna brava (3000–5000 m) for the Arequipa region, terms also used by Troll (1968). Cabrera (1968) and Schnell (1987) used the terms “provincia altoandina” referring to 4250 m up to 5000 m and “provincia puneña” for 3250 to 4250 m. Based on altitude and type of vegetation of the Andean regions of North Moquegua we presented a revised classification (following the phytosociological reviews by Montesinos et al. 2012; Montesinos-Tubée et al. 2015b and chapter 5). The altitudinal zonation runs as follows: prepuna (3400–3800 m), puna (3800–4500 m), superpuna (4500–>4800 m). The classification has been applied for other such regions in South Peru, Bolivia and Argentina (Tosi 1960, Huber & Riina 1997, Reese & Liu 2005).

Studies of the phytogeography of the Peruvian Andes flora started with a first approach to the worldwide distribution of Peruvian flora presented by Weberbauer (1936). Several decades later, new studies presented important information on the phytogeography of Peru (Gutte 1992; Galán de Mera et al. 1997; Linares-Palomino 2002; Weigend 2002; Kuentz et al. 2007). Other important contributions treating the phytogeography of the puna are those by Arroyo et al. (1982), Simpson (1983), Lewis et al. (1990), López (2003) and López & Zambrana-Torrelio (2006). Important work on the biogeography of the Peruvian Andes was done by Rivas-Martínez & Tovar (1983) and Weigend (2002). Phytogeographical analyses have been performed of floristic lists that include páramo and puna from Colombia, Ecuador, Peru, Bolivia, Argentina and Chile (Arroyo et al. 1982; Cano et al. 2010; Cleef 1979; Cooper et al. 2010; Flores et al. 2005; Galiano 1990; Gutte 1985, 1986; Lozano et al. 2009; Luebert & Gajardo 2005; Montesinos-Tubée 2011a, 2012a,b, 2013b, 2014b, 2015b; Montesinos-Tubée & Kool 2015; Orellana 2014; Pestalozzi & Torrez 1998; Ruthsatz 1977; Seibert & Menhofer 1991, 1992, 1993; Smith 1988; Teillier 1998, 1999; Tovar 2009; Villagrán et al. 1983; Yurapaitán & Albán 2003).

The aim of this study is to analyse the phytogeographical affinities of the flora of the prepuna, puna and superpuna of North Moquegua in order to obtain a better understanding of the origin, diversity and distribution of its flora. Particular emphasis is given to the analysis of the floristic connections of the North Moquegua flora with the flora of the neighbouring puna of Peru and other floras of the northern and southern Andes.

Methods

Study area

The northern Andes of Moquegua is located in the southern Andean regions of Peru, approximately 138 km northeast of the Pacific Ocean and 61 km west of Lake Titicaca (Fig. 1). The study region (Table 1) is located in the districts of Ichuña, Yunga, Ubinas and Lloque (General Sanchez Cerro Province) at 70°44’33”, 70°26’59” W and 16° 06’37”, 16°16’30” S. The climate is characterised by a rainy season. According to the climatic records of the Ubinas (3400 m) and Ichuña (3780 m) stations, the amount of daily rainfall is variable and occurs in approximately 70 days/year. Maximum precipitation occurs during February-March. Average total yearly precipitation is about 500 mm and relative humidity attains almost 40% throughout the year. Average total maximum temperature during the day is 13.1° C, minimum temperature 7.4° C and annual mean temperature 10.8° C; the lowest temperatures recorded are between –15 and –20° C (above 4400 m), –1 to –6° C (above 3500 m) and occur in June; the highest temperatures are 17 to 21° C and occur in September (pers. data from 2005 and 2012). At 3500 m, dominant wind directions are S, SW, SE and NW, with a recorded average speed of 3.5–6 km/h; the maximum recorded wind speed was 45 km/h, NE in September 2005.

The vegetation of the highlands of North Moquegua is characterised by a mosaic of puna formations (Table 1):
1. Prepuna (scrublands, spiny scrubs, xerophytic formations within scrublands, sandy river banks with cyclic succession, active and abandoned agricultural terraces, rocky slopes, humid grasslands, halophytic communities, caves with water seeping out of the rocks and afforestation stands of introduced trees) distributed between 3400 and 3800 m;
2. Puna (scrublands, grasslands, *Puya raimondii* patches with tussocks and shrubs, rocky slopes, ravines, agricultural terraces, abandoned terrain, tree patches with *Escallonia myrtilloides*, humid grasslands, caves with water seeping out of the rocks and metamorphic formations) distributed between 3800 and 4500 m;
3. Superpuna (rocky slopes, plateaus with grasslands and cushions, scree slopes with copper minerals, manure communities, cryoturbate terrains, temporary and permanent lakes, cushion-bog peats and caves with water seeping out of the rocks) distributed between 4500 and 4800 m (Montesinos et al. 2012; Montesinos-Tubée et al. 2015b, submitted).

Data collection

Data were collected from phytosociological and floristic studies done by Montesinos et al. (2012), Montesinos-Tubée (2011, 2012a,b, 2013, 2014, 2015), Montesinos-Tubée & Kool (2015) and Montesinos-Tubée et al. (2015b). Data was also taken from chapter 5. Plant collections made by the first author in North Moquegua were additionally studied. Herbarium specimens of most species had been deposited at the Herbario San Marcos, Universidad Nacional Mayor de San Marcos (Lima), at the Herbario CUZ of the Universidad Nacional San Antonio Abad del Cusco, at the Herbario HUSA (Universidad Nacional de San Agustín) in Arequipa, at Herbario HSP (Instituto Científico Michael O. Dillon) in Arequipa, at Herbario MOL of the Universidad Nacional Agraria La Molina in Lima, at HUPCH (Herbario Magdalena Pavlich of the Universidad Peruana Cayetano Heredia) in Lima, at the Herbario CPUN of the Universidad Nacional de

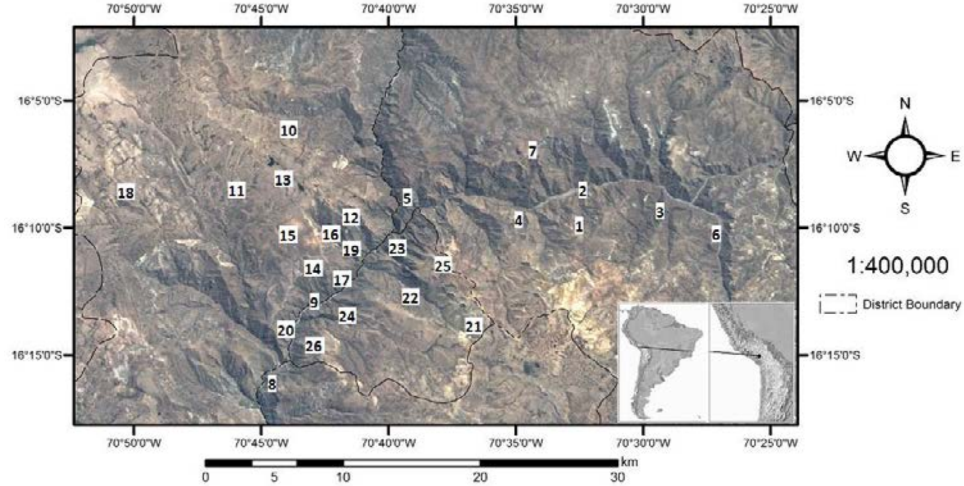


Figure 1. Location of the upper reaches of the Tambo and Ichuña rivers in the Andes of Moquegua, Peru. The black lines indicate the district boundaries. The numbers show the locations of the study sites as listed in table 1. Image source: Landsat 7 Enhanced Thematic. Mapper (ETM+) Acquisition date = 10 May, 2001. Glovis Visualization Portal (http://www.glovis.usgs.gov), a part of the Earth Resources and Science Center (EROS) of the USGS.

Cajamarca in Peru, at the herbarium MO from the Missouri Botanical Gardens and at the L-WAG herbarium at Naturalis in Leiden.
The study and full inventory of the flora of the whole highlands of North Moquegua range started in 2005 and is still ongoing. Preliminary accounts of the vascular flora are presented by Montesinos-Tubée (2011, 2012a,b, 2015b). Several new records for the flora, as well as species new to science, have been documented for Moquegua (Montesinos-Tubée 2013a, 2014b; Montesinos-Tubée & Kool 2015). A species inventory was done for the prepuna, puna and superuna (descriptions presented in 1, 2 and 3).

Additional information was obtained from herbarium collections and the database of Herbario San Marcos USM, UNMSM in Lima. Supplementary data was obtained from other national and international herbaria: B, BR, CPUN, CUZ, F, HSP, HUPCH, HUSA, L, LPB, MO, MOL, P and WAG. The data set includes a total of 531 vascular plant taxa belonging to 257 genera that are listed in appendix 1.

The present geographical distribution for each vascular genus has been determined on the basis of Brako & Zarucchi (1993) and Tropicos (2015) and occasionally also using recent phylogenetic studies (e.g. Freire et al. 2015: *Belloa*; Tate et al. 2005: *Tarasa, Fuertesimalva*). Species distributions were also determined using the literature and Tropicos (2015).

Table 1. Background information for the 26 study sites in the highlands of North Moquegua (Southern Peru).

	Name site	District	Year(s) study	Elevation	Coordinates	km2 area	Zone	Region	Type environment
1	Coriri, Qhaqhaskinkri	Ichuña	2009	4000–4540	16°09'43" S 70°31'48" W	48.3	zonal, azonal	puna, superpuna	plateau grasslands with cushions, grazed grasslands, occasional lakes
2	Ichuña	Ichuña	2009, 2012	3840–4050	16°08'28" S 70°32'11" W	2.91	zonal, azonal	puna	grassland, *Puya raimondii*, chasmophyte, perturbed terrains, humid grassland, ravines, river shores
3	Italpallune	Ichuña	2009	3900–4050	16°08'52" S 70°29'25" W	1.49	zonal	puna	grassland, chasmophyte, abandoned terraces
4	Santa Cruz de Oyo Oyo	Ichuña	2009	4000–4250	16°09'55" S 70°34'53" W	1.52	zonal, azonal	puna	*Puya raimondii* , chasmophyte, humid grassland
5	Sefincane	Ichuña	2009, 2013	3580–4000	16°09'41" S 70°39'40" W	2.46	zonal	puna, prepuna	scrubland, abandoned terraces, chasmophyte
6	Tolapampa	Ichuña	2012	4000–4250	16°09'43" S 70°27'09" W	3.45	zonal, azonal	puna	grassland, chasmophyte, perturbed grasslands
7	Yanapuquio, Cachilaya, Condorwasi, Puca Saya (Yanahuara)	Ichuña	2009, 2012	3780–4780	16°07'29" S 70°33'43" W	11.02	zonal, azonal	puna, superpuna	chasmophyte, scree slopes with copper, agriculture terraces, plateau grasslands with cushions, rocky slopes, open plateaus, manure communities
8	Lucco	Lloque	2012, 2013	3450–3800	16°16'04" S 70°44'24" W	6.4	zonal	prepuna, puna	chasmophyte, scrublands, grasslands
9	Camata	Ubinas	2009, 2011	3500–3800	16°12'40" S 70°43'07" W	4.6	zonal, azonal	prepuna	agriculture terraces, humid grasslands, scrublands
10	Coalaque	Ubinas	2009	4300–4500	16°06'05" S 70°43'36" W	4.3	zonal, azonal	puna	grasslands, scree, humid grasslands, perturbed terrains
11	Gasawasi-Witopata (Querala)	Ubinas	2009, 2011	4500–4640	16°08'32" S 70°45'33" W	14.44	zonal, azonal	puna, superpuna	plateau grasslands with cushions, open plateaus, humid grasslands, cushion-bog peats
12	Pachamayo, Qalo-Qalo	Ubinas	2012	3500–3800	16°10'42" S 70°41'08" W	0.46	zonal	prepuna	rocky slopes, scrublands
13	Pacosani, Jallpacocha, Yaretaq, Larsepesca (Lakes)	Ubinas	2009, 2011, 2013, 2014	4615–4700	16°07'54" S 70°43'59" W	15.34	zonal, azonal	superpuna	plateau grasslands with cushions, rocky slopes, lakes, humid grasslands, cushion-bog peats
14	Patune	Ubinas	2009, 2013	4050–4400	16°11'39" S 70°43'50" W	28.61	zonal, azonal	puna	grassland, chasmophyte, scrubland, humid grasslands
15	Pirhuani chico, Pirhuani grande	Ubinas	2011, 2014	4470–4660	16°10'18" S 70°43'25" W	3.84	zonal	superpuna	plateau cushion communities and grasslands
16	Rancho, Punku (Tassa)	Ubinas	2009, 2011-2014	3900–4500	16°09'56" S 70°42'25" W	8.51	zonal, azonal	puna	grassland, *Puya raimondii* , scrubland, humid grasslands, caves, lava formations, manure communities
17	Qaqawara, Qellepunku	Ubinas	2009, 2013	3500–3900	16°12'09" S 70°41'51" W	3.65	zonal, azonal	prepuna, puna	scrubland, grassland, perturbed terrain, river shore, chasmophyte
18	Road between Carmen Chaclaya and Matazo	Ubinas	2011, 2013, 2014	4460–4590	16°07'09" S 70°48'38" W	27.5	zonal, azonal	superpuna	grazed grasslands with cushions, manure communities, rocky slopes, humid grasslands, cushion-bog peats
19	Tassa	Ubinas	2009-2014	3500–3900	16°11'03" S 70°41'32" W	1.89	zonal, azonal	prepuna	scrublands, terraces, ravines, chasmophyte
20	Yanarico (Camata)	Ubinas	2009	3520–3540	16°13'25" S 70°43'34" W	1.01	zonal	prepuna	scrubland, abandoned terraces
21	Choco-Choco environs	Yunga	2012	4660–4760	16°14'43" S 70°36'56" W	17.93	zonal, azonal	superpuna	grasslands with cushions, scree slopes, humid grasslands, open plateaus with cushions, cushion-bog peats
22	Yunga, Chojo	Yunga	2009-2013	3550–4550	16°12'33" S 70°39'32" W	15.4	zonal	prepuna	scrubland, abandoned terraces
23	Jatuntio-Arapa	Yunga	2009, 2013	3580–3700	16°10'53" S 70°40'18" W	3.14	zonal	prepuna	scrubland
24	Pampilla, Yinquipampa, Huañasco, Jatunpaccha	Yunga	2009-2013	3500–4400	16°13'10" S 70°41'26" W	6.84	zonal, azonal	prepuna, puna	grassland, chasmophyte, waterfall, ravine, humid grasslands, abandoned terraces, scrublands
25	Sura, Perusa-Chaquisura, Siliaca, Yanasaya, Kasullama	Yunga	2009-2013	3900–4800	16°11'26" S 70°38'54" W	17.41	zonal, azonal	puna, superpuna	chasmophyte, rocky slopes, Puya raimondii, plateau grasslands with cushions, grasslands, scree, humid grasslands, open plateaus with cushions, cushion-bog peats
26	Toreqaqa, Exchaje	Yunga	2009-2013	3470–3520	16°14'49" S 70°43'46" W	3.13	zonal, azonal	prepuna	scrubland, caves, halophytic, humid grasslands

The floristic relation in terms of genera of the highlands of North Moquegua to other Andean floras of the northern, central and southern Andes (nine additional datasets) was analysed. Floristic lists from each site were obtained from the literature (Table 2).

The accounts of the different highland floras were carefully examined for recent taxonomic revisions. The inventory resulted in a data matrix of ten Andean floras and the presence/absence of 770 genera. This data matrix was classified using a Farthest Neighbor (single linkage) dendrogram method with the Sørensen (Bray-Curtis) ratio as distance measure (PC-Ord 4, McCune & Mefford 1999). For gradient analysis we used principal components analysis (PCA) (Ter Braak & Šmilauer 2002)

Phytogeographical elements: analysis at genus level

The phytogeographical analysis at the genus level was carried out by comparing the data from different geographical areas in South America (Table 2). In addition, data on distribution of genera was obtained from Tropicos (2015) after an analysis of the occurrence of different genera and species by means of distribution maps and collections of specimens found above 3000 m. Other references for genus distributions across South America were also analysed (Vuilleumier & Monasterio 1986; Al-Shehbaz 1989; Tovar 1993; Kiesling 1994; Jørgensen et al. 1995; Romoleroux et al. 1995; Funk 1997; Dhooge et al. 2003; López 2003; Sklenář & Balslev 2005; Weigend 2005; Wood 2006; Pinto & Luebert 2009; León et al. 2010; Dillon & Luebert 2014; Zárate et al. 2015). Appendix 1 presents the complete list of genera evaluated from South America compared with the Moqueguan flora.

The phytogeographical elements were defined based on those from the literature (Cleef 1979; López & Beck 2002; López 2003; López & Zambrana-Torrelio 2006; Kuentz et al. 2007; Sklenář & Balslev 2007; Mabberley 2008; Moreira-Muñoz 2011 and Lozano et al. 2009). Nine phytogeographical elements were recognised for the study area (Table 3).

Table 2. Reference information for the data set of eight Andean floras used for comparative multivariate analysis.

High Andes Region	Elevation (m)	Approx Prec. (mm/year)	Number of genera considered	Sources
THIS STUDY: South Peru (Moquegua)	3400–4800	~ 500	257	Montesinos 2011, 2012a,b, 2013, 2014, 2015
NW Bolivia (Kalla Waya)	3500–5200	500	239	Seibert & Menhofer 1991, 1992, 1993
Cochabamba (SW Bolivia)	3800–4500	~ 500	176	Pestalozzi & Torrez 1998
Central Peru (Junín)	3000–4700	~ 500	217	Gutte 1985, 1986; Yurapaitán & Albán 2003; Flores et al. 2005
Central Peru (Ancash)	3240–5200	~ 800	327	Smith 1988; Monsalve & Cano 2005; Cano et al. 2010
Cusco (S Peru)	3000–5200	580	274	Galiano 1990
North Peru (Cajamarca)	3000–4300	650–1370	234	Tovar 2009; Cooper et al. 2010
Colombian Cordillera Oriental (Páramos)	2500–4800	700–3000	271	Cleef 1979
Ecuador	3800	3000–5000	180	Lozano et al. 2009
Parinacotas, Huaylillas (N Chile)	3500–5000	316	191	Arroyo et al. 1982; Teillier 1998, 1999; Luebert & Gajardo 2005; Orellana 2013
NW Argentina (Salta Province)	3500–4900	~ 500	230	Ruthsatz 1977

Results

Flora diversity and taxonomic composition

The vascular flora of north Moquegua is composed of a total of 553 taxa. These includes 10 families, 17 genera, and 22 species of ferns; 1 family, 1 genus and three species of gymnosperms, and 60 families, 239 genera, and 506 species of angiosperms, of which 423 species are Dicots and 83 Monocots. The taxa include subspecies and varieties in *Conyza, Hypochaeris, Perezia, Mutisia, Tanacetum* (Asteraceae), *Ullucus* (Basellaceae), *Cumulopuntia, Neowerdermannia* (Cactaceae) and *Plantago* (Plantaginaceae), which for simplicity were treated in the same way as species in the analyses (as were six confirmed new species for which publication is in preparation).

Species diversity is unevenly distributed among taxonomic groups (Fig. 2). In general, the most species-rich families are Asteraceae, Poaceae, Malvaceae, Brassicaceae, Fabaceae, followed by Cactaceae and Caryophyllaceae. The most diverse genera are *Senecio* (Asteraceae), *Nototriche* (Malvaceae), *Astragalus* (Fabaceae), *Plantago* (Plantaginaceae), *Solanum* (Solanaceae) and *Werneria* (Asteraceae) (Tables 4 and 5).
Asteraceae entirely dominate the flora and together with Poaceae comprise one-third of the total species diversity. Other families are conspicuously less diverse and there are 23 families with a single species.

Distribution of genera in prepuna, puna and superpuna

Of the 257 genera encountered in the Andean mountains of Moquegua, 185 occur in the prepuna (3400–3800 m), 148 genera in the puna (3800–4500 m) and 99 genera in the superpuna (4500–4800 m) (Figure 2). The analysis was made based on herbarium collections by the first author and phytosociological relevés (Montesinos et al. 2012; Montesinos-Tubée et al. 2015b, submitted). The species and genus diversity of the families and the species diversity of genera are given in Tables 4 and 5.

Eighty-eight genera are unique to the prepuna, being Amaranthaceae, Boraginaceae, Cactaceae, Solanaceae and Verbenaceae, families that are common across the landscape at 3400–3800 m. Moreover, 19 genera occur only in the puna (Alstroemeriaceae: *Alstroemeria*; Apiaceae: *Niphogeton*; Asteraceae: *Ageratina*, *Coreopsis*, *Misbrookea* and *Plagiocheilus*; Caryophyllaceae: *Stellaria*; Dryopteridaceae: *Elaphoglossum* and *Polystichum*; Fabaceae: *Vicia*; Grossulariaceae: *Ribes*; Lamiaceae: *Hedeoma*; Ophioglossaceae: *Ophioglossum*; Poaceae: *Triniochloa* and *Vulpia*; Polypodiaceae: *Campyloneurum* and *Polypodium*; Rosaceae: *Aphanes*, and Scrophulariaceae: *Limosella*). Finally, 20 genera are restricted to the superpuna (Asteraceae: *Erigeron, Leucheria, Mniodes, Oritrophium, Werneria* and *Xenophyllum*; Campanulaceae: *Lobelia*; Cyperaceae: *Phylloscirpus, Trichophorum* and *Zameioscirpus*; Juncaceae: *Distichia* and *Oxychloe*; Montiaceae: *Montia*; Orchidaceae: *Myrosmodes*; Plantaginaceae: *Callitriche*; Poaceae: *Aciachne, Agrostis, Anthochloa, Dielsiochloa* and *Dissanthelium*).

Various genera are widespread in the prepuna, puna and superpuna at an altitudinal range of 3400–4800 m: *Bomarea* (Alstroemeriaceae); *Gomphrena* (Amaranthaceae); *Bowlesia* (Apiaceae); *Asplenium* (Aspleniaceae); *Baccharis, Belloa, Conyza, Hypochaeris, Parastrephia, Perezia* and *Senecio* (Asteraceae); *Lepidium* and *Mancoa* (Brassicaceae); *Cumulopuntia* and *Lobivia* (Cactaceae); *Paronychia* and *Spergularia* (Caryophyllaceae);

Crassula (Crassulaceae); *Cyperus* (Cyperaceae); *Ephedra* (Ephedraceae); *Adesmia, Astragalus* and *Lupinus* (Fabaceae); *Gentiana* and *Gentianella* (Gentianaceae); *Geranium* (Geraniaceae); *Luzula* (Juncaceae); *Caiophora* (Loasaceae); *Tarasa* (Malvaceae); *Aa* (Orchidaceae); *Bartsia* and *Castilejja* (Orobanchaceae); *Oxalis* (Oxalidaceae); *Plantago* (Plantaginaceae); *Festuca, Hordeum, Muhlenbergia, Poa* and *Stipa* (Poaceae); *Lachemilla* (Rosaceae); *Galium* (Rubiaceae); *Salpichroa* & *Solanum* (Solanaceae); *Urtica* (Urticaceae) and *Junellia* (Verbenaceae).

Table 3. The generic composition of geographical flora elements in the Andean mountains of Moquegua, South Peru.

Element	Definition	Genus
Tropical		
Puna (P)	Genera distributed in the Central-South Andes mountains.	*Adesmia* DC., *Anthochloa* Nees & Meyen, *Austrocylindropuntia* Backeb., *Balbisia* Cav., *Belloa* J. Rémy, *Chaetanthera* Ruiz & Pav., *Chersodoma* Phil., *Clinanthus* Herb., *Corryocactus* Britton & Rose, *Cumulopuntia* F. Ritter, *Dielsiochloa* Pilg., *Dissanthelium* Trin., *Echinopsis* Zucc., *Hypseocharis* J. Rémy, *Junellia* Moldenke, *Ligaria* Tiegh., *Lophopappus* Rusby, *Lobivia* Britton & Rose, *Mastigostyla* I.M. Johnst. *Misbrookea* V.A. Funk, *Montiopsis* Kuntze, *Mostacillastrum* O.E. Schulz, *Neowerdermannia* Frič, *Niphogeton* Schltdl., *Ophryosporus* Meyen, *Oreocereus* (A. Berger) Riccob., *Oxychloe* Phil., *Oziroe* Raf., *Parastrephia* Nutt., *Polyachyrus* Lag., *Proustia* Lag., *Pycnophyllum* Remy, *Quinchamalium* Molina, *Tephrocactus* Lem., *Tunilla* D.R. Hunt & Iliff, *Weberbauera* Gilg & Muschl., *Zameioscirpus* Dhooge & Goetgh.
Andean Alpine (AA)	Genera distributed in the Andes mountains.	*Aa* Rchb. f., *Aciachne* Benth., *Aristeguietia* R.M. King & H. Rob., *Barnadesia* Mutis ex L. f., *Bowlesia* Ruiz & Pav., *Brayopsis* Gilg & Muschl., *Caiophora* C. Presl, *Cantua* Juss. ex Lam., *Chuquiraga* Juss., *Cremolobus* DC., *Diplostephium* Kunth, *Distichia* Nees & Meyen, *Dunalia* Kunth, *Helogyne* Nutt., *Jamesonia* Hook. & Grev., *Loricaria* Wedd., *Mniodes* (A. Gray) A. Gray ex Benth. & Hook. f., *Mutisia* L. f., *Myrosmodes* Rchb. f., *Nototriche* Turcz., *Perezia* Lag., *Phylloscirpus* Boerner, *Plagiocheilus* Arn. ex DC., Plazia Ruiz & Pav., *Polylepis* Ruiz & Pav., *Puya* Molina, *Salpichroa* Miers., *Stenomesson* Herb., *Tetraglochin* Poepp., *Ullucus* Caldas, *Xenophyllum* V.A. Funk.

Neotropical Montane (NM)	Genera found in tropical America, including some outliers in temperate America.	*Ageratina* Spach, *Anredera* Juss., *Aphanes* L., *Apodanthera* Arn., *Argyrochosma* (J. Sm.) Windham, *Baccharis* L., *Bomarea* Mirb., *Bouteloua* Lag., *Campyloneurum* C. Presl, *Cardionema* DC., *Chaptalia* Vent., *Cyclospermum* Lag., *Dalea* L., *Echeveria* DC., *Exhalimolobos* Al-Shehbaz & C.D. Bailey, *Facelis* Cass., *Guilleminea* Kunth, *Heterosperma* Cav., *Lachemilla* (Focke) Rydb., *Laennecia* Cass., *Lepechinia* Willd., *Lucilia* Cass., *Lycianthes* (Dunal) Hassl., *Monnina* Ruiz & Pav., *Nama* L., *Nassella* (Trin.) E. Desv., *Nothoscordum* Kunth, *Opuntia* Mill., *Oritrophium* (Kunth) Cuatrec., *Schinus* L., *Schkuhria* Roth., *Stevia* Cav., *Tagetes* L., *Tarasa* Phil., *Tillandsia* L., *Triniochloa* Hitchc., *Tropaeolum* L., *Urocarpidium* Ulbr., *Vasquezia* Phil., *Viguiera* Kunth, *Werneria* Kunth, *Zephyranthes* Herb.
Wide Tropical (PT)	Genera common in the tropics of at least two continents.	*Achyrocline* (Less.) DC., *Alternanthera* Forssk., *Buddleja* L., *Conyza* Less., *Dichondra* J.R. Forst. & G. Forst., *Elaphoglossum* Schott ex J. Sm., *Gomphrena* Raf., *Ipomoea* L., *Nicotiana* L., *Otholobium* C.H. Stirt., *Passiflora* L., *Pellaea* Link, *Peperomia* Ruiz & Pav. *Phyla* Lour., *Portulaca* L.
Temperate		
Austral-Antarctic (AA)	Genera with origin in the cool Southern hemisphere.	*Alstroemeria* Dumort., *Azorella* Lam., *Calandrinia* Kunth, *Calceolaria* L., *Cortaderia* Stapf., *Cotula* L., *Distichlis* Raf., *Escallonia* Mutis ex L. f., *Leucheria* Lag., *Lilaeopsis* Greene, *Olsynium* Raf., *Oreomyrrhis* Endl., *Ourisia* Comm. ex Juss., *Plagiobothrys* Fisch. & C.A. Mey., *Sicyos* L., *Sisyrinchium* L., *Wahlenbergia* Schrad. ex Roth.
Holarctic (HA)	Genera with origin in the Northern Hemisphere.	*Arenaria* L., *Astragalus* L., *Bartsia* L., *Bromus* L., *Castilleja* Mutis ex L. f., *Cerastium* L., *Draba* L., *Epilobium* L., *Erigeron* L., *Gentiana* L., *Gentianella* Moench, *Hordeum* L., *Hypochaeris* L., *Lathyrus* L., *Lupinus* L., *Muhlenbergia* Schreb., *Oenothera* L., *Phlox* L., *Ribes* L., *Salvia* L., *Satureja* L., *Saxifraga* L., *Sedum* L., *Silene* L., *Stachys* L., *Trifolium* L., *Vicia* L.

Wide temperate (WT)	Genera in temperate parts in both hemispheres, including páramo and puna.	*Agrostis* L., *Amsinckia* Lehm., *Calamagrostis* Adans., *Carex* L., *Cheilanthes* Sw., *Chenopodium* L., *Cystopteris* Bernh., *Descurainia* Webb & Berthel., *Ephedra* L., *Festuca* L., *Galinsoga* Ruiz. & Pav., *Galium* L., *Gamochaeta* Wedd., *Geranium* L., *Gnaphalium* L., *Hieracium* L., *Isolepis* R. Br., *Juncus* L., *Limosella* L., *Luzula* DC., *Melica* L., *Mimulus* L., *Mirabilis* L., *Montia* L., *Plantago* L., *Poa* L., *Ranunculus* L., *Rumex* L., *Senecio* L., *Sisymbrium* L., *Trichophorum* Pers., *Trisetum* Pers., *Urtica* L., *Valeriana* L., *Viola* L., *Vulpia* C.C. Gmel., *Woodsia* R. Br.
Anti Tropical (AT)	Genera found in both the northern and southern temperate tropics.	*Aloysia* Paláu, *Cistanthe* Spach, *Coreopsis* L., *Cryptantha* Lehm. ex G. Don, *Cylindropuntia* (Engelm.) F.M. Knuth, *Frankenia* L., *Gilia* Ruiz & Pav., *Gochnatia* Kunth, *Grindelia* Willd., *Hedeoma* Pers., *Mancoa* Wedd., *Pectocarya* DC. ex Meisn., *Phacelia* Juss.
Cosmopolitan (COSM)	Genera widely distributed in tropical and temperate parts of the world.	*Adiantum* L., *Ambrosia* L., *Aristida* L., *Asplenium* L., *Atriplex* L., *Azolla* Lam., *Bidens* L., *Callitriche* L., *Crassula* L., *Cynanchum* L., *Cyperus* L., *Eleocharis* R. Br., *Equisetum* L., *Eragrostis* Wolf, *Euphorbia* L., *Heliotropium* L., *Lepidium* L., *Lobelia* L., *Melpomene* A.R. Sm. & R.C. Moran, *Ophioglossum* L., *Oxalis* L., *Parietaria* L., *Paronychia* Mill., *Polypodium* L., *Polypogon* Desf., *Polystichum* Roth, *Rhynchospora* Vahl, *Salicornia* L., *Schoenoplectus* (Rchb.) Palla, *Solanum* L., *Spergularia* (Pers.) J. Presl & C. Presl, *Sporobolus* R. Br., *Stellaria* L., *Stipa* L., *Thelypteris* Schmidel, *Triglochin* L., *Verbena* L., *Xanthium* L.

Table 4. The most species-rich families from the vascular flora of the highlands of North Moquegua (South Peru). # gen. refers to the total number of genera, # spp. to the total number of species and E denotes the total number of endemic species.

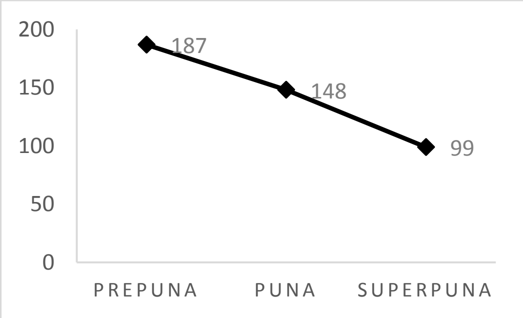
Family	# G	# spp.
Asteraceae	53	141 (17)
Poaceae	28	50
Brassicaceae	13	28 (2)
Fabaceae	11	26 (2)
Malvaceae	4	23 (5)
Caryophyllaceae	8	21 (3)
Cactaceae	10	18 (7)
Solanaceae	5	15
Plantaginaceae	4	15(1)
Apiaceae	7	11

Family	# G	# spp.
Caprifoliaceae	3	11 (2)
Amaranthaceae	6	11
Boraginaceae	7	9 (1)
Pteridaceae	5	9
Cyperaceae	8	8
Orobanchaceae	2	8
Pteridaceae	4	8
Gentianaceae	2	7 (3)
Onagraceae	2	7 (1)
Iridaceae	2	6 (1)

Table 5. The most species-rich genera found in the highlands of North Moquegua (South Peru).

Genera	Family	# spp.
Senecio	Asteraceae	31 (11)
Nototriche	Malvaceae	14 (5)
Plantago	Plantaginaceae	10(1)
Solanum	Solanaceae	10
Werneria	Asteraceae	10
Astragalus	Fabaceae	9
Calamagrostis	Poaceae	9
Belloa	Asteraceae	8
Perezia	Asteraceae	8 (1)
Valeriana	Caprifoliaceae	8 (2)
Hypochaeris	Asteraceae	7 (1)
Bartsia	Orobanchaceae	6
Cumulopuntia	Cactaceae	6 (2)
Gentianella	Gentianaceae	6 (3)
Lepidium	Brassicaceae	6 (1)
Lupinus	Fabaceae	6 (2)
Oxalis	Oxalidaceae	6
Paronychia	Caryophyllaceae	6 (2)
Poa	Poaceae	6
Tarasa	Malvaceae	6

Figure 2. Number of genera found in the prepuna, puna and superpuna in our study area in North Moquegua.



Geographical composition of genera

The generic composition of phytogeographical elements in the puna biome of North Moquegua (South Peru) is represented in Table 3 and Figures 3, 4 and 5.

1. Tropical component

The percentage of the different elements is based on the total of 257 genera.

- The proportion of the puna element is about 14% (37 genera) and this element is almost equally represented in the prepuna (3400–3800 m) and the superpuna (4500–4800 m). With 10.8 % it is less represented in the puna zone (3800–4500 m). The Puna element comprises those genera restricted to the Central Andes and is well represented by 37 genera, which include a variety of growth forms such as columnar cacti, shrubs, ground rosettes, annual herbs and grasses, bulbs, cushions and mats. The genera *Oziroe, Mastygostyla* and *Clinanthus* are characteristic of the prepuna. Cushions are well represented by *Pycnophyllum*, which occurs in the puna and more broadly in the superpuna. Other genera characteristic of bogs from the superpuna are *Oxychloe* and *Zameioscirpus.*
- The Andean-Alpine element is represented by 12% (31 genera), with the highest proportion in the superpuna. The Andean-Alpine element is best represented by the Asteraceae, with fourteen genera with different distributions across the prepuna, puna and superpuna.
- More than 15% (42 genera) are neotropical montane, with major representation in the prepuna and puna and lowest proportion in the superpuna.
- The Wide Tropical element consists of genera common in the tropics of at least two continents and is represented in the study area by 15 genera (5.8%), two of them small trees: *Buddleia* and *Otholobium*, both species from the prepuna. Other genera of the wide tropical element are represented by small ground rosettes and creeping plants, such as those found in the genera *Paronychia, Phyla, Ipomoea and*

Gomphrena. Some genera occur in highlands all over the tropics and some are exclusively African-American or Asian-American. This element includes families with only one genus, the two exceptions being Amaranthaceae (*Alternanthera* and *Gomphrena*) and Asteraceae (*Achyrocline* and *Conyza*).

2. Temperate component

Ninety-four genera are of temperate distribution (36.6%).

- Wide Temperate element genera are distributed in temperate and cool regions of both hemispheres. This element is represented in the study area by 37 genera (14.4%). Poaceae account for seven genera (*Agrostis, Calamagrostis, Festuca, Melica, Poa Trisetum* and *Vulpia*) and are most species-rich family in the Wide Temperate element. Five of the genera belong to the Asteraceae and other families have less than four genera.
- The Antitropical element is mainly disjunctive and comprises genera found both in the subtropical northern and southern temperate regions, but absent from the intervening tropics. In Moquegua it is represented by 13 genera, three of which belong to Asteraceae (*Coreopsis, Gochnatia* and *Grindelia*) and three to Boraginaceae (*Cryptantha, Pectocarya* and *Phacelia*). Most of the genera occur in the prepuna, with a few exceptions such as *Hedeoma* (Lamiaceae) and *Gilia* (Polemoniaceae).
- Austral-Antarctic element genera have southern temperate distributions. This element is represented by seventeen genera (6.6%). Among them, three genera (*Azorella, Lilaeopsis* and *Oreomyrrhis*) were recorded from the Apiaceae family in the puna and prepuna; Asteraceae are represented by only two genera (*Cotula* and *Leucheria*) and Iridaceae by two genera (*Olsynium* and *Sisyrinchium*).
- Holarctic element genera have northern temperate distributions, including the Mediterranean climate distribution. Twenty-seven genera with Holarctic distribution (10.5%) were found in the study area. The family Caryophyllaceae is represented by three genera (*Arenaria, Cerastium* and *Silene*) from the puna and superpuna, rarely in the prepuna. Fabaceae is the richest family representing the Holarctic element with five genera (*Astragalus, Lathyrus, Lupinus, Trifolium* and *Vicia*) well represented in the prepuna, puna and superpuna.

3. Cosmopolitan element

- Cosmopolitan element genera are those with worldwide distributions. The Cosmopolitan element is represented in the study area by thirty-eight genera (15%). With 32 genera the prepuna communities have higher numbers of cosmopolitan genera: 20 genera occur in the puna and 11 in the superpuna. The relatively high proportion of cosmopolitan species in the prepuna can be attributed to the relatively high number of introduced species on agricultural terraces and in abandoned cropland.

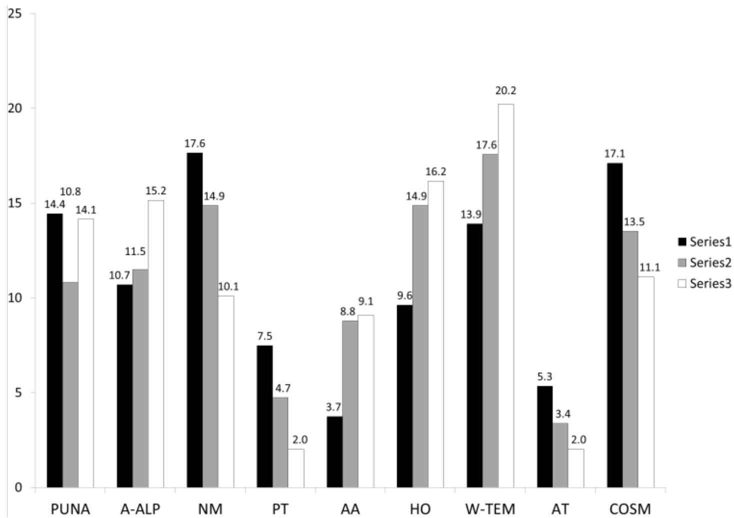


Figure 3. Proportions of elements (%) per vegetation zone (prepuna, puna and superpuna) of all genera from the highlands of North Moquegua.

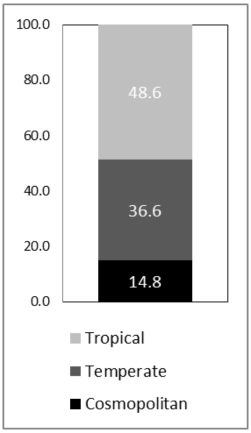


Figure 4. Proportions (%) of phytogeographical components of the prepuna, puna and superpuna in North Moquegua (South Peru).

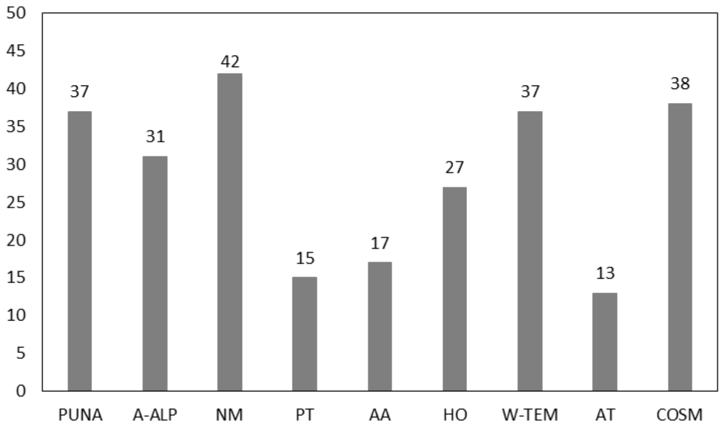


Figure 5. Total number of genera per phytogeographical element found in North Moquegua (South Peru).

Puna-páramo flora relationships

Figure 6 is the dendrogram showing the generic similarity between a selection of the Andean highland sites. In the graph at just above 25% similarity, two main groups can be recognised. Group one consists of North Moquegua, North of Chile and Northwest Argentina. Of all the generic floras, North Moquegua is most similar to the floras of North of Chile and Northwest Argentina. In the second group, Colombia and Ecuador are split off from the other remaining genera lists because of their low level of similarity. The generic composition of Colombia and Ecuador are highly related (more than 90% similarity).

At the next level, Junín and Ancash (Central Peru) are divided from Bolivia, Cusco (South Peru) and Cajamarca (North Peru). The Bolivian Andean flora shows a very high similarity to the Cusco flora (S Peru) and more distant relationship with Cajamarca (N Peru). The cluster comprising these regions is attributed to their proximity to the lowlands of Amazonia with high atmospheric humidity.

In the PCA (Figure 7) the main variation in the generic flora (axis 1) can be interpreted as a geographical gradient, while the second main variation (axis 2) could be interpreted in terms of atmospheric humidity: xeric versus pluvial conditions. From left to right the ordination diagram shows an increase in precipitation in which the tropical alpine floras are ordered as follows: less than 350 mm/year, (NW Chile); ~500 mm/year (Northwest Argentina, Moquegua, Junín, Bolivia); ~580 mm/year (Cusco); 650–1370 mm/year (Cajamarca); ~800 mm/year (Ancash Cordillera Blanca and Cordillera Negra); 3000–5000 mm/year (Ecuador); 700–3000 mm/year (Colombian Cordillera Oriental), (see Table 2).

Figure 6 shows a gradient from arid-xeric in the upper cluster of the dendrogram to increasing atmospheric humidity in the lower cluster. The cluster of Colombia and Ecuador represents the humid páramo biome. Cajamarca is situated in the region of the jalca, the transition between the puna and páramo biomes. Ancash represents the Cordillera Blanca and Cordillera Negra, which have the highest summits of the Peruvian Andes and a more humid type of puna (or dry páramo). Páramo biomes are said to end in Chachapoyas (Amazonas region), but there is evidence from the Cusco area (Galiano 1992) and Bolivia (Beck 1985, 1998) that páramos extend South to Bolivia along the upper forest line. However, more floristic and vegetation evidence is needed on this topic.

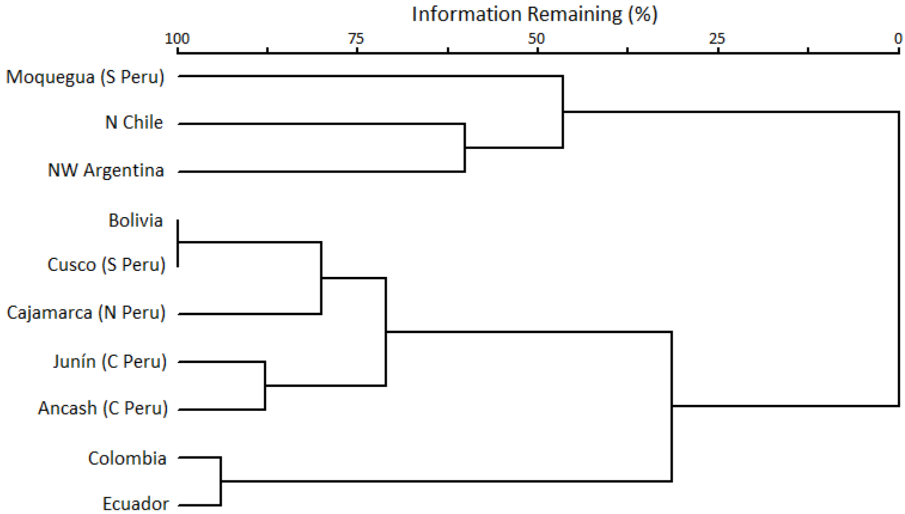


Figure 6. Farthest Neighbor Dendrogram based on the presence/absence of 787 genera (Sørensen (Bray-Curtis) distance measure) and showing the floristic similarity between the 10 Andean sites.

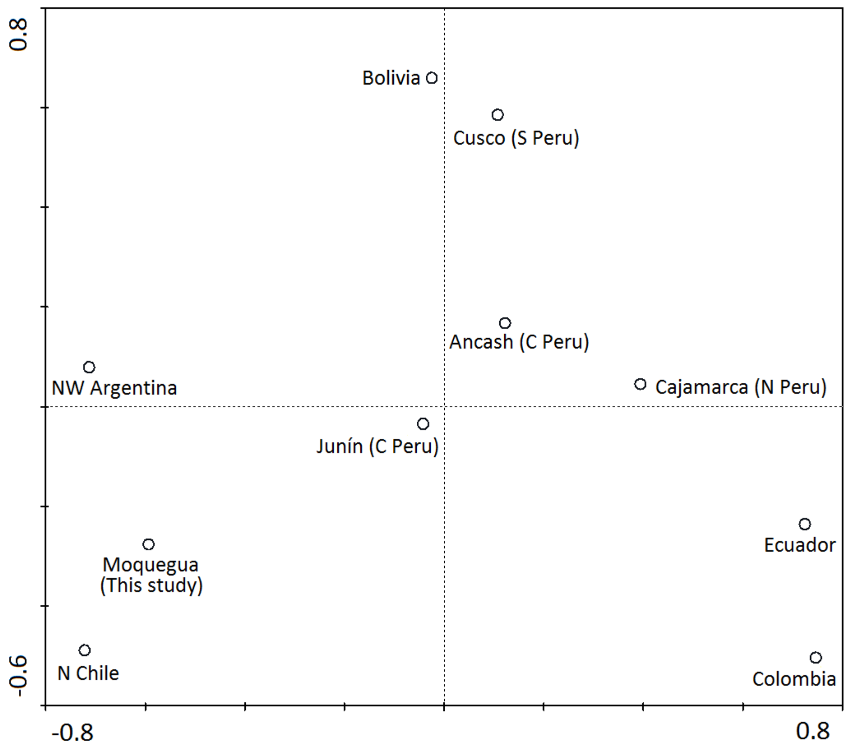


Figure 7. PCA ordination based on genera composition of 10 Andean flora datasets. (a) PCA Axis 1 Eig= 0.265; Axis 2 Eig= 0.144.

Discussion

Floristic features

We have been able to list 257 vascular genera for the highlands of North Moquegua. They have been assigned to the three geographical flora elements and nine phytogeographical elements as outlined above (Figs 3 and 5). 125 genera (48.6%) belong to the Andes-Tropical component and 94 genera (36.6%) belong to the Temperate component. 38 genera (14.9%) could be assigned to the Cosmopolitan element.

The genera *Senecio, Nototriche, Astragalus, Plantago, Solanum, Valeriana* and *Werneria* included the highest numbers of species (Tables 4 and 5). The high diversity of the genus *Senecio* with 29 species is remarkable. It contains 11 endemics, including several species new to science (described by Montesinos-Tubée 2014b and others yet undescribed). *Nototriche* (Malvaceae) is also a rich genus, with 18 species (including 8 endemics), mainly occurring in the superpuna. *Plantago* comprises 10 species, including subspecies and varieties, most of them from the prepuna and puna. The genus *Werneria* (Asteraceae) is reported with 10 species from the superpuna. *Valeriana, Astragalus* and *Solanum*, each with 10 species, are also species-rich genera with significant presence in the prepuna and puna.

With 58 endemic species, endemism in the highlands of North Moquegua is not particularly high in terms of proportion of the total flora (10.9%). This percentage is higher if perennial species only are considered (mostly woody), including cacti. Gentry (1986) refers to the percentage of endemism in different plant formations in areas of up to 75,000 km². As an example of an isolated arid environment, in the region of Antofagasta, Chile, 38.7% of the species are endemic in the Atacama Desert region. Even higher percentages (of up to 60%) are found for single-species formations within the region (Squeo et al. 1998). Another example is the Arequipa Province in South Peru, where 26.7% of the species are endemic (Montesinos-Tubée et al. 2015a). By contrast, in an area of the Puna of Chile, which is less isolated than the Atacama Desert, only 7% of species are local endemics (Teillier, 1998).

The north of Moquegua contains numerous hotspots of high species richness and endemism. Some of these hotspots are associated with calcareous bedrock, but the majority of these sites occur on volcanic substrates. Montesinos-Tubée (2013a, 2014b) and Montesinos-Tubée & Kool (2015) recently described a significant number of new species for the region. In addition, the first author expects to publish a few more new species soon. The highest numbers of endemic species are found in the prepuna and superpuna and the highest numbers of species new to science have been found in the superpuna. These highland habitats have provided stable environments during a sufficiently long period to allow the evolution of distinct paired species. Various pairs of closely related endemic species in the genera *Senecio, Gentianella, Cumulopuntia, Valeriana, Paronychia, Lupinus, Nototriche* and *Viola* occur with geographically disjunct distributions on eastern and western mountains ranges divided by the Tambo River valley, suggesting these isolated sites have long existed.

Highland flora relations

López & Beck (2002) and López (2003) reported the close affinities of the Prepuna of southern Bolivia to the flora of central-southern South America (Argentina, Paraguay and southern Brasil). We compared the flora of our study area with the highland flora of the Kalla Walla and Cochabamba regions in the Central Andes of Bolivia (Seibert & Menhofer 1991, 1992, 1993; Pestalozzi & Torrez 1998). We found that the flora of the Moqueguan highlands is strongly related to the flora of northern Chile and north-western Argentina. The southern and central geographical regions of the Moquegua department seem to be less diverse in plant species composition (Arakaki & Cano 2003; Chancayauri 2008; Schwarzer et al. 2010; Gutiérrez Tito 2013), which is attributable to their drier conditions. The first author analysed weather satellite maps for the past ten years, concluding that North Moquegua is the wettest geographical region of the department. This is one of the factors explaining the high diversity of plant species, which is comparable to that of neighbouring regions such as Puno, Tacna and Arequipa.

With respect to the páramo biome, it is well known from the literature (e.g. Luteyn 1999) that its southern border is the "jalca" around Cajamarca and Chachapoyas in North Peru. However, there is evidence of the presence of páramo from the Cusco area (A. M. Cleef 2015, pers. comm., 12 December) and longer ago from Bolivia (S. Beck 2015, pers. comm., 12 December). It seems that the páramo biome extends south to Bolivia along the Amazonian upper forest line. Much more floristic vegetation evidences is needed to confirm this.

Generic geographical flora composition

On the basis of the studies of NW Argentina (Ruthsatz 1977) and the Andes of North Chile (Teillier 1998, 1999; Luebert & Gajardo 2005; Orellana 2013) and the botanical collections stored at Missouri Botanical Garden (Tropicos 2014) we expected that altitude and humidity would be important factors that determine the floristic composition of North Moquegua. The close relationship of these regions to the Moqueguan flora can be attributed to the drier conditions of the puna highlands, which are more or less comparable with those in Northwest Argentina and North of Chile. The flora of the puna regions of Central Peru, Cusco in South Peru and the Andean regions of Bolivia are much less closely related, which is attributed to these areas being wetter than Moquegua. The more distant relationship is also explained by the proximity to warm tropical regions, which leads to the presence of several neotropical montane genera.

Several genera that occur at altitudes below 3400 m in the Moquegua region indicate the close relationship to the Atacama flora (see also Schwarzer et al. 2010). In our study we ignored the genera listed by Schwarzer et al. (2010), since our study focused on the limits of the prepuna in Moquegua.

The conservation of the Moqueguan mountain environments should be prioritised for the preservation of these fragile and diverse ecosystems (Montesinos-Tubée 2011a). Biological and ecological guidelines have been proposed by Gutiérrez Tito (2012, 2013), who strongly recommends establishing a large nature reserve in North Moquegua. The results of the research presented in this thesis can be used as a framework for the designation of nature reserves and nature conservation planning.

Appendix 1. Genera found in different regions of South America in comparison to Moquegua (S Peru). For references see methods. MOQ= Moquegua (South Peru), BOL=Bolivia (Bolivian Andes), JUN=Junín (Central Peru), ANC=Ancash (Central Peru), CUS=Cusco (South Peru), CAJ=Cajamarca (North Peru), COL=Colombia, ECU=Ecuador, CHI=Chile (North Chile), ARG=Argentina (Northwest Argentina).

	Geographical area	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
	Number of genera	257	433	263	361	365	318	337	346	244	349
Genera	Family										
Aa Rochb. f.	Orchidaceae	x	x		x	x	x	x	x	x	x
Abromeitiella Mez	Bromeliaceae										x
Abutilon Mill.	Malvaceae		x				x				x
Acacia Mill.	Fabaceae									x	x
Acaena Mutis ex L.	Rosaceae		x	x	x	x	x	x	x	x	
Acalypha L.	Euphorbiaceae					x					
Acantholippia Griseb.	Verbenaceae									x	x
Acaulimalva Krapov.	Malvaceae		x	x	x	x	x	x	x		x
Achyrocline (Less.) DC.	Asteraceae	x	x	x	x	x	x	x	x		x
Aciachne Benth.	Poaceae	x	x	x	x	x	x	x	x		
Adesmia DC.	Fabaceae	x	x							x	x
Adiantum L.	Pteridaceae	x	x		x	x			x		
Aegiphila Raf.	Lamiaceae		x			x					
Aegopogon Humb. & Bonpl. Ex Willd.	Poaceae		x		x	x	x	x			
Aetanthus (Eichler) Engl.	Loranthaceae							x	x		
Agalinis Raf.	Orobanchaceae		x		x						
Ageratina Spach	Asteraceae	x	x	x	x	x	x	x	x		
Agrostis L.	Poaceae	x	x	x	x	x	x	x	x		x
Agrostopoa Davidse, Soreng & P.M. Peterson	Poaceae							x			
Allionia L.	Nyctaginaceae										x
Alonsoa Ruiz & Pav.	Scrophulariaceae		x	x	x	x	x	x	x	x	
Alopecurus L.	Poaceae		x	x	x	x		x	x		
Aloysia Paláu	Verbenaceae	x				x					
Alstroemeria L.	Alstroemeriaceae	x	x		x					x	
Altensteinia Kunth	Orchidaceae		x	x		x	x	x	x		
Alternanthera Forssk.	Amaranthaceae	x	x	x	x		x				x
Amaranthus L.	Amaranthaceae		x			x					x
Ambrosia L.	Asteraceae	x		x		x				x	
Amicia Kunth	Fabaceae										x
Amsinckia Lehm.	Boraginaceae	x	x							x	
Anadenanthera Speg.	Fabaceae		x								
Anredera Juss.	Basellaceae	x									
Antennaria Gaertn.	Asteraceae			x			x		x		
Anthericum L.	Asparagaceae		x	x	x	x	x	x			
Anthobryum Phil.	Frankeniaceae									x	x
Anthochloa Nees & Meyen	Poaceae	x			x					x	x
Anthurium Schott	Araceae								x		
Antidaphne Poepp. & Endl.	Santalaceae							x	x		
Aphanactis Wedd.	Asteraceae			x	x		x	x	x		
Aphanelytrum (Hack.) Hack.	Poaceae							x			
Aphanes L.	Rosaceae	x	x	x							
Aphanostelma Schltr.	Apocynaceae										x
Aphyllocladus Wedd.	Asteraceae										x
Apodanthera Arn.	Cucurbitaceae	x				x					x
Aragoa Kunth	Plantaginaceae							x			
Arcytophyllum Willd. Ex Schult. & Schult. f.	Rubiaceae		x	x	x	x	x	x	x		
Arenaria L.	Caryophyllaceae	x	x	x	x	x	x	x		x	x

Genera	Family \ Geogr. area	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Argyrochosma (J. Sm.) Windham	Pteridaceae	x	x	x	x	x	.	.	.	x	x
Aristeguietia R.M. King & H. Rob.	Asteraceae	x	.	x	x	x	x	.	.	.	.
Aristida L.	Poaceae	x	x	x	x	x	x	.	.	.	x
Arjona Tiegh.	Schoepfiaceae	.	x	.	.	.	.	.	.	.	.
Arracacia Bancr.	Apiaceae	.	x	.	.	.	x	x	x	.	.
Aschersoniodoxa Gilg & Muschl.	Brassicaceae	.	x	.	x	x	.	.	.	.	x
Asplenium L.	Aspleniaceae	x	x	x	x	x	x	x	x	.	x
Asteriscium Cham. & Schltdl.	Apiaceae	.	.	.	.	.	.	.	.	.	x
Astragalus L.	Fabaceae	x	x	x	x	x	x	.	.	x	x
Athyrium Roth.	Woodsiaceae	.	x	.	x	.	.	x	x	.	.
Atriplex L.	Amaranthaceae	x	.	.	.	.	.	.	.	x	x
Aulonemia Gougot	Poaceae	.	.	.	.	.	.	x	x	.	.
Austrocylindropuntia Backeb.	Cactaceae	x	x	.	.	.	.	.	.	.	x
Azolla Lam.	Salviniaceae	x	x	x	x	x	x	x	x	x	.
Azorella Lam.	Apiaceae	x	x	x	x	x	x	x	x	x	x
Baccharis L.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Balbisia Cav.	Vivianiaceae	x	x	.	.	.	.	.	.	x	x
Barnadesia Mutis ex L. f.	Asteraceae	x	x	x	x	x	x	x	x	.	.
Barneoudia Gay	Ranunculaceae	.	.	.	.	.	.	.	.	.	x
Bartsia L.	Orobanchaceae	x	x	x	x	x	x	x	x	x	x
Basella L.	Basellaceae	.	x	.	.	x	.	.	.	.	.
Begonia L.	Begoniaceae	.	.	x	x	x	.	.	.	.	.
Bejaria Mutis	Ericaceae	.	x	.	.	x	.	x	x	.	.
Belloa J. Rémy	Asteraceae	x	x	x	x	x	x	x	x	x	x
Belonanthus Graebn.	Caprifoliaceae	.	.	x	.	.	x	.	.	.	.
Berberis L.	Berberidaceae	.	x	x	x	x	x	x	x	.	.
Bidens L.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Bipinnula Comm. ex A. Juss.	Orchidaceae	.	.	.	.	.	.	.	.	x	.
Blakiella Cuatrec.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Blechnum L.	Blechnaceae	.	x	.	x	x	x	x	x	.	.
Bocconia L.	Papaveraceae	.	x	.	.	x	.	x	x	.	.
Boerhavia L.	Nyctaginaceae	.	x	x	.	.	.	.	x	.	x
Bomarea Mirb.	Alstroemeriaceae	x	x	x	x	x	x	x	x	.	.
Borreria G. Mey.	Rubiaceae	.	.	.	.	.	.	x	.	.	x
Bothriochloa Kuntze	Poaceae	.	x	.	.	.	x	.	.	.	x
Botrychium Sw.	Ophioglossaceae	.	.	.	.	.	x	.	.	.	.
Bougainvillea Comm. ex Juss.	Nyctaginaceae	.	.	.	.	.	.	.	.	.	x
Bouteloua Lag.	Poaceae	x	x	x	x	x	.	.	.	x	x
Bowlesia Ruiz & Pav.	Apiaceae	x	x	.	x	x	.	.	.	x	x
Brachyotum (DC.) Triana	Melastomataceae	.	x	x	x	x	x	x	x	.	.
Brachypodium P. Beauv.	Poaceae	.	.	x	x	.	x	x	.	.	.
Brayopsis Gilg & Muschl.	Brassicaceae	x	x	x	x	x	.	x	x	.	x
Bromus L.	Poaceae	x	x	x	x	x	x	x	x	x	x
Brugmansia Pers.	Solanaceae	.	.	x	.	x	x	.	.	.	.
Bucquetia DC.	Melastomataceae	.	.	.	.	.	.	x	x	.	.
Buddleja L.	Scrophulariaceae	x	x	x	x	x	.	x	.	.	x
Bulbostylis Kunth	Cyperaceae	.	.	.	x	.	x	x	x	.	.
Bulnesia Gay	Zygophyllaceae	.	.	.	.	.	.	.	.	.	x
Cacosmia Kunth	Asteraceae	.	.	.	.	.	x	.	x	.	.
Caesalpinia L.	Fabaceae	.	x	.	.	x	.	.	.	.	x
Caiophora C. Presl.	Loasaceae	x	x	x	x	x	x	.	.	x	x
Calamagrostis Adans.	Poaceae	x	x	x	x	x	x	x	x	.	x
Calandrinia Kunth	Montiaceae	x	x	x	x	x	.	x	x	x	x
Calceolaria L.	Calceolariaceae	x	x	x	x	x	x	x	x	x	x

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Cologania Kunth	Fabaceae	.	x	.	.	x	.	x	.	.	.
Columellia Ruiz & Pav.	Columelliaceae	.	.	.	x	x	.	.	.	.	.
Commelina L.	Commelinaceae	.	x	.	x	x	x	x	x	.	x
Conyza Less.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Coreopsis L.	Asteraceae	x	.	x	x	.	x	.	.	x	.
Coriaria L.	Coriariaceae	.	.	x	x	.	x	x	x	.	.
Coronopus Zinn	Brassicaceae	.	x	.	.	.	.	.	.	.	x
Corryocactus Britton & Rose	Cactaceae	x	.	.	.	x	.	.	.	x	.
Cortaderia Stapf	Poaceae	x	x	x	x	x	x	x	x	x	x
Cosmos Cav.	Asteraceae	.	.	x	x	x	.	x	.	.	.
Cottea Kunth	Poaceae	.	.	.	.	.	.	.	.	.	x
Cotula L.	Asteraceae	x	x	x	x	.	x	x	x	x	x
Coursetia DC.	Fabaceae	.	x	.	.	.	x	.	x	.	x
Cranichis Sw.	Orchidaceae	.	.	.	.	.	x	x	.	.	.
Crassula L.	Crassulaceae	x	x	.	x	x	x	x	x	.	x
Cremolobus DC.	Brassicaceae	x	.	.	x	.	.	.	x	.	.
Cristaria Cav.	Malvaceae	.	.	.	.	.	.	.	.	x	.
Cronquistianthus R.M. King & H. Rob.	Asteraceae	.	.	.	.	x	x	.	.	.	.
Crotalaria L.	Fabaceae	.	.	.	.	x	.	.	.	.	.
Croton L.	Euphorbiaceae	.	.	.	x	x	.	.	.	.	.
Cryptantha Lehm. ex G. Don	Boraginaceae	x	.	.	.	.	.	.	.	x	x
Cuatrecasasiella H. Rob.	Asteraceae	.	.	x	x	x	.	.	.	.	.
Cumulopuntia F. Ritter	Cactaceae	x	x	.	.	.	.	.	.	x	.
Cuphea P. Browne	Lythraceae	.	x	.	.	x	x	x	.	.	.
Cuscuta L.	Convolvulaceae	.	x	.	.	x	.	.	.	.	.
Cybianthus Mart.	Primulaceae	.	.	.	.	.	.	.	x	.	.
Cyclanthera Schrad.	Cucurbitaceae	.	x	.	.	x	.	.	x	.	x
Cyclospermum Lag.	Apiaceae	x	x	.	.	.	x	.	.	.	.
Cylindropuntia (Engelm.) F.M. Knuth	Cactaceae	x	.	.	.	.	.	.	.	.	.
Cynanchum L.	Apocynaceae	x	x	x	x	x	x	.	.	x	x
Cypella Herb.	Iridaceae	.	x	.	.	x	.	.	.	.	.
Cyperus L.	Cyperaceae	x	x	x	x	x	x	x	.	x	x
Cystopteris Bernh.	Cystopteridaceae	x	x	.	x	.	.	x	.	x	x
Dalea L.	Fabaceae	x	.	.	x	x	x	.	.	x	x
Danthonia DC.	Poaceae	.	.	.	.	.	.	x	x	.	.
Dasyphyllum Kunth	Asteraceae	.	.	.	x	x	.	.	.	.	.
Delostoma D. Don	Bignoniaceae	.	.	.	.	.	x	.	.	.	.
Dendrophorbium (Cuatrec.) C. Jeffrey	Asteraceae	.	.	.	.	.	.	.	x	.	.
Dendrophthora Eichler	Santalaceae	.	x	.	.	x	.	x	x	.	.
Dennstaedtia Bernh.	Dennstaedtiaceae	.	x	.	.	.	.	.	.	.	.
Deschampsia P. Beauv.	Poaceae	.	.	.	.	.	.	.	.	x	.
Descurainia Webb & Berthel.	Brassicaceae	x	x	x	x	x	.	.	.	x	x
Desfontainesia Hoffmanns.	Oleaceae	.	.	.	.	.	.	x	x	.	.
Desmodium Desv.	Fabaceae	.	.	.	.	.	x	.	.	.	.
Diastatea Scheidw.	Campanulaceae	.	.	.	.	x	.	.	.	.	.
Dichondra J.R. Forst. & G. Forst.	Convolvulaceae	x	x	x	x	.	x	.	.	.	x
Dicliptera Juss.	Acanthaceae	.	.	.	.	.	x	.	.	.	.
Dielsiochloa Pilg.	Poaceae	x	.	.	x	.	.	.	.	x	x
Digitaria Haller	Poaceae	.	.	.	.	.	.	.	.	.	x
Dinoseris Griseb.	Asteraceae	.	.	.	.	.	.	.	.	.	x
Dioidia L.	Rubiaceae	.	.	.	.	.	x	.	x	.	.
Dioscorea L.	Dioscoreaceae	.	.	.	x	x	.	.	.	x	.
Diplachne P. Beauv.	Poaceae	.	.	.	.	.	.	.	.	.	x
Diplostephium Kunth	Asteraceae	x	x	x	x	x	x	x	x	x	.

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Diplotaxis DC.	Brassicaceae	.	.	x	.	.	.	.	.	.	.
Dissanthelium Trin.	Poaceae	x	x	x	x	x	.	.	.	.	.
Disterigma (Klotzsch) Nied.	Ericaceae	.	x	.	.	x	x	x	x	.	.
Distichia Nees & Meyen	Juncaceae	x	x	x	x	x	x	x	x	x	x
Distichlis Raf.	Poaceae	x	.	.	.	.	.	.	.	x	x
Ditassa R. Br.	Apocynaceae	.	.	.	.	.	.	x	.	.	.
Dodonaea Mill.	Sapindaceae	.	x	.	x	x	.	.	x	.	.
Dorobaea Cass.	Asteraceae	.	.	.	.	.	x	.	x	.	.
Draba L.	Brassicaceae	x	x	x	x	.	.	x	x	x	.
Drymaria Willd. ex Schult.	Caryophyllaceae	.	x	x	x	x	x	x	x	.	.
Duchesnea Sm.	Rosaceae	.	.	.	.	.	x	.	x	.	.
Dunalia Kunth	Solanaceae	x	x	x	.	x	.	.	.	x	.
Duranta L.	Verbenaceae	.	x	.	x	x	.	.	.	.	.
Dysopsis Baill.	Euphorbiaceae	.	x	.	.	.	.	x	.	.	.
Eccremis Willd. ex Baker	Xanthorrhoeaceae	.	.	.	.	x	x	x	x	.	.
Echeveria DC.	Crassulaceae	x	x	.	x	x	x	x	x	.	.
Echinochloa P. Beauv.	Poaceae	.	x	.	.	.	.	.	.	.	.
Echinopsis Zucc.	Cactaceae	x	x	x	.	x	.	.	.	x	x
Eclipta L.	Asteraceae	.	.	x	.	.	.	.	.	.	.
Elaphoglossum Schott ex J. Sm.	Dryopteridaceae	x	x	.	x	x	x	x	x	.	.
Elatine L.	Elatinaceae	.	x	.	x	.	.	x	.	.	.
Eleocharis R. Br.	Cyperaceae	x	x	x	x	.	x	x	x	x	x
Elleanthus C. Presl	Orchidaceae	.	.	.	.	.	.	x	x	.	.
Elodea Michx.	Hydrocharitaceae	.	x	x	x	.	.	.	.	x	.
Elymus L.	Poaceae	.	x	x	x	.	x	.	.	.	.
Elytrigia Desv.	Poaceae	.	.	.	x	.	.	.	.	.	.
Englerocharis Muschl.	Brassicaceae	.	x	x	x	.	.	.	.	.	.
Enneapogon Desv. ex P. Beauv.	Poaceae	.	.	.	.	.	.	.	.	.	x
Ephedra L.	Ephedraceae	x	x	x	x	x	.	.	.	x	x
Epidendrum L.	Orchidaceae	.	x	.	x	x	x	x	x	.	.
Epilobium L.	Onagraceae	x	x	x	x	x	x	x	.	x	.
Equisetum L.	Equisetaceae	x	x	.	x	.	.	x	x	.	.
Eragrostis Wolf	Poaceae	x	x	.	x	x	x	.	.	x	x
Erechtites Raf.	Asteraceae	.	x	x	.	x	x	.	x	.	.
Eremocharis Phil.	Apiaceae	.	.	.	.	x	.	.	.	.	.
Erigeron L.	Asteraceae	x	x	x	x	.	.	x	.	.	.
Eriocaulon L.	Eriocaulaceae	.	.	.	.	.	.	x	x	.	.
Eriosorus Fée	Pteridaceae	.	.	.	x	.	x	x	x	.	.
Eryngium L.	Apiaceae	.	x	x	x	.	x	x	x	x	.
Erythrina L.	Fabaceae	.	.	.	.	x	x	.	.	.	.
Escallonia Mutis ex L. f.	Escalloniaceae	x	x	x	x	x	x	x	x	.	.
Espeletia Mutis ex Bonpl.	Asteraceae	.	.	.	.	.	.	x	x	.	.
Espeletiopsis Cuatrec.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Eudema Bonpl.	Brassicaceae	.	.	.	.	.	.	.	.	x	x
Eugenia L.	Myrtaceae	.	.	.	.	.	.	x	.	.	.
Euphorbia L.	Euphorbiaceae	x	x	x	x	x	x	x	.	.	x
Eustephia Cav.	Amaryllidaceae	.	.	.	.	x	.	.	.	.	.
Eustephiopsis R.E. Fr.	Amaryllidaceae	.	.	.	.	.	.	.	.	.	x
Evolvulus L.	Convolvulaceae	.	x	.	.	.	x	.	.	.	x
Exhalimolobos Al-Shehbaz & C.D. Bailey	Brassicaceae	x	.	.	x	.	.	.	.	.	.
Fabiana Ruiz & Pav.	Solanaceae	.	.	.	.	.	.	.	.	x	x
Facelis Cass.	Asteraceae	x	x	.	.	.	x	.	.	.	x
Festuca L.	Poaceae	x	x	x	x	x	x	x	x	x	x
Flaveria Juss.	Asteraceae	.	x	.	.	x	.	.	.	.	x

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Floscaldasia Cuatrec.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Flourensia DC.	Asteraceae	.	x	.	.	x	.	.	.	.	x
Fortunatia J.F. Macbr.	Asparagaceae	.	.	.	.	x	.	.	.	.	.
Fragaria L.	Rosaceae	.	x	.	.	x	.	.	.	x	.
Frankenia L.	Frankeniaceae	x	.	.	.	.	.	.	.	x	.
Fuchsia Sw.	Onagraceae	.	.	.	x	x	.	x	x	.	.
Furcraea Vent.	Asparagaceae	.	x	.	x	x	x	.	x	.	.
Gaiadendron G. Don	Loranthaceae	.	x	.	.	x	.	x	x	.	.
Galinsoga Ruiz & Pav.	Asteraceae	x	x	.	x	x	x	.	.	.	x
Galium L.	Rubiaceae	x	x	x	x	x	x	x	x	x	x
Gamochaeta Wedd.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Gaultheria L.	Ericaceae	.	.	x	x	x	x	x	x	.	.
Gaylussacia Kunth	Ericaceae	.	.	.	.	.	.	x	.	.	.
Geissanthus Hook. f.	Primulaceae	.	.	.	.	.	.	x	x	.	.
Gentiana L.	Gentianaceae	x	x	x	x	x	x	x	x	x	x
Gentianella Moench	Gentianaceae	x	x	x	x	x	x	x	x	x	x
Geranium L.	Geraniaceae	x	x	x	x	x	x	x	x	.	x
Gerardia Benth.	Orobanchaceae	.	.	.	.	.	.	.	.	.	x
Geum L.	Rosaceae	.	.	.	.	.	x	.	x	.	.
Gilia Ruiz & Pav.	Polemoniaceae	x	x	.	x	.	.	.	.	x	x
Glandularia J.F. Gmel.	Verbenaceae	.	.	.	x	.	.	.	.	x	.
Gleichenia Sm.	Gleicheniaceae	.	.	.	x	.	.	x	x	.	.
Gnaphalium L.	Asteraceae	x	x	x	x	x	x	x	.	x	x
Gochnatia Kunth	Asteraceae	x	.	.	.	.	.	.	.	.	x
Gomphichis Lindl.	Orchidaceae	.	.	.	x	.	.	x	x	.	.
Gomphrena L.	Amaranthaceae	x	x	.	.	x	.	.	.	x	x
Gorgonidium Schott	Araceae	.	x	.	.	x	.	.	.	.	x
Grammadenia Benth.	Primulaceae	.	.	.	.	.	.	x	.	.	.
Grammitis Sw.	Polypodiaceae	.	.	.	x	x	.	x	x	.	.
Gratiola L.	Plantaginaceae	.	.	.	.	.	.	x	.	.	.
Greigia Regel	Bromeliaceae	.	.	.	.	.	.	x	x	.	.
Grindelia Willd.	Asteraceae	x	x	.	.	.	.	.	.	x	.
Guilleminea Kunth	Amaranthaceae	x	x	.	.	x	.	.	.	.	x
Gunnera L.	Gunneraceae	.	x	.	.	.	.	.	x	.	.
Gutierrezia Lag.	Asteraceae	.	.	.	.	.	.	.	.	.	x
Guzmania Ruiz & Pav.	Bromeliaceae	.	.	.	.	.	.	.	x	.	.
Gymnocalycium Pfeiff. ex Mittler	Cactaceae	.	.	.	.	.	.	.	.	.	x
Gymnomitrium Mitt.	Gymnomitriaceae	.	x	.	.	.	.	.	.	.	.
Gynoxys Cass.	Asteraceae	.	.	.	x	x	x	x	x	.	.
Hackelia Opiz	Boraginaceae	.	.	x	x	x	.	x	.	.	.
Halenia Borkh.	Gentianaceae	.	.	x	x	x	x	x	x	.	.
Halimolobus Wittst.	Brassicaceae	.	.	.	.	.	.	x	.	.	.
Hebecladus Miers	Solanaceae	.	.	.	.	x	.	.	.	.	.
Hedeoma Pers.	Lamiaceae	x	x	x	.	x	.	.	.	.	.
Helianthopsis H. Rob.	Asteraceae	.	.	.	x	.	.	.	.	.	.
Heliopsis Pers.	Asteraceae	.	x	x	.	x	.	x	.	.	.
Heliotropium L.	Boraginaceae	x	x	.	.	x	.	.	x	x	x
Helogyne Nutt.	Asteraceae	x	.	.	.	x	.	.	.	x	.
Herissantia Medik.	Malvaceae	.	.	.	.	.	.	.	.	.	x
Herniaria L.	Caryophyllaceae	.	x	.	.	.	.	.	.	.	x
Hesperomeles Lindl.	Rosaceae	.	.	x	x	x	x	x	x	.	.
Heterosperma Cav.	Asteraceae	x	x	.	.	.	x	.	.	.	x
Hieracium L.	Asteraceae	x	x	.	x	x	x	x	.	.	x
Hierochloe R. Br.	Poaceae	.	.	.	x	.	.	x	.	.	.

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Hoffmannseggia Cav.	Fabaceae	.	.	.	.	.	.	.	.	x	x
Hordeum L.	Poaceae	x	x	x	x	x	.	.	.	.	x
Huperzia Bernh.	Lycopodiaceae	.	.	.	x	x	x	.	x	.	.
Hybanthus Jacq.	Violaceae	.	.	.	.	.	x	.	.	.	.
Hydrocotyle L.	Araliaceae	.	x	.	.	.	x	x	x	.	.
Hymenophyllum Sm.	Hymenophyllaceae	.	.	.	.	.	.	x	x	.	.
Hypericum L.	Hypericaceae	.	x	x	x	x	x	x	.	.	.
Hypochaeris L.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Hypolepis Bernh.	Dennstaedtiaceae	.	x	.	x	.	.	x	.	.	x
Hypoxis L.	Hypoxidaceae	.	x	.	.	x	.	.	x	.	x
Hypseocharis J. Rémy	Geraniaceae	x	x	x	x	.	.	.	.	.	x
Hyptis Jacq.	Lamiaceae	.	x	.	x	x	x	x	x	.	x
Ilex L.	Aquifoliaceae	.	.	.	.	.	.	x	x	.	.
Iochroma Benth.	Solanaceae	.	x	.	x	.	.	.	x	.	x
Ipomoea L.	Convolvulaceae	x	x	x	.	x	.	.	.	.	x
Iresine P. Browne	Amaranthaceae	.	x	.	.	x	.	.	x	.	x
Isidrogalvia Ruiz & Pav.	Tofieldiaceae	.	.	.	.	.	.	.	x	.	.
Isoetes L.	Isoetaceae	.	x	.	x	.	x	x	x	.	.
Isolepis R. Br.	Cyperaceae	x	x	.	x	.	x	x	x	.	.
Jaborosa Juss.	Solanaceae	.	x	.	.	.	.	.	.	x	.
Jaegeria Kunth	Asteraceae	.	x	.	x	.	.	x	x	.	.
Jalcophila M.O. Dillon & Sagást.	Asteraceae	.	x	x	.	.	.	.	x	.	.
Jaltomata Schltdl.	Solanaceae	.	x	.	x	x	.	.	.	.	.
Jamesonia Hook. & Grev.	Pteridaceae	x	.	.	x	.	.	x	x	.	.
Juglans L.	Juglandaceae	.	.	.	.	x	.	.	.	.	.
Juncus L.	Juncaceae	x	x	x	x	x	x	x	.	.	x
Junellia Moldenke	Verbenaceae	x	x	.	.	.	.	.	.	x	x
Jungia L. f.	Asteraceae	.	x	.	x	x	x	.	.	.	.
Justicia L.	Acanthaceae	.	x	.	x	x	x	x	x	.	x
Kageneckia Ruiz & Pav.	Rosaceae	.	.	.	x	x	.	.	.	.	.
Kallstroemia Scop.	Zygophyllaceae	.	x	.	.	x	.	.	x	.	.
Kaunia R.M. King & H. Rob.	Asteraceae	.	x	.	.	.	.	.	.	.	.
Kentrothamnus Suess. & Overkott	Rhamnaceae	.	.	.	.	.	.	.	.	.	x
Koeleria Pers.	Poaceae	.	x	x	.	x	.	.	.	.	x
Krameria Loefl.	Krameriaceae	.	.	.	.	x	x	.	.	x	x
Krapfia DC.	Ranunculaceae	.	.	.	x	x	.	.	x	.	.
Lachemilla (Focke) Rydb.	Rosaceae	x	x	x	x	x	x	x	x	x	x
Laennecia Cass.	Asteraceae	x	.	.	.	.	.	.	.	.	.
Laestadia Kunth ex Less.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Lamourouxia Kunth	Orobanchaceae	.	.	.	.	.	x	.	x	.	.
Lampaya Phil. ex Murillo	Verbenaceae	.	.	.	.	.	.	.	.	x	x
Lantana L.	Verbenaceae	.	x	.	x	.	x	.	.	.	x
Lappula Moench	Boraginaceae	.	.	.	.	.	.	x	.	.	.
Larrea Cav.	Zygophyllaceae	.	.	.	.	.	.	.	.	.	x
Lathyrus L.	Fabaceae	x	x	.	x	x	x	x	.	.	.
Lellingeria A.R. Sm. & R.C. Moran	Polypodiaceae	.	.	.	.	.	.	x	.	.	.
Lemna L.	Araceae	.	x	.	x	.	.	.	.	x	.
Lepechinia Willd.	Lamiaceae	x	x	x	x	x	.	.	.	.	.
Lepidium L.	Brassicaceae	x	x	x	x	x	.	.	.	x	x
Lesquerella S. Watson	Brassicaceae	.	.	.	.	.	.	.	.	.	x
Leucheria Lag.	Asteraceae	x	.	.	x	.	.	.	.	x	.
Libanothamnus Ernst	Asteraceae	.	.	.	.	.	.	x	.	.	.
Ligaria Tiegh.	Loranthaceae	x	x	.	.	.	.	.	.	.	x
Lilaea Bonpl.	Juncaginaceae	.	.	.	x	.	.	x	x	.	.

Genera	Family \ Geogr. area	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Lilaeopsis Greene	Apiaceae	x	x	x	x	.	x	x	x	x	x
Limosella L.	Scrophulariaceae	x	x	x	x	.	.	x	.	.	x
Linum L.	Linaceae	.	.	.	x	.	x	.	.	.	.
Lippia L.	Verbenaceae	.	x	.	.	.	.	x	.	.	x
Lithospermum L.	Boraginaceae	.	.	x	x	.	x	.	.	.	.
Llagunoa Ruiz & Pav.	Sapindaceae	.	.	.	.	.	x	.	.	.	.
Loasa Adans.	Loasaceae	.	x	.	x	x	.	.	.	.	.
Lobelia L.	Campanulaceae	x	x	x	x	x	x	x	.	x	x
Lobivia Britton & Rose	Cactaceae	x	x	.	.	.	.	.	.	.	x
Lomatia R. Br.	Proteaceae	.	.	.	.	.	x	.	.	.	.
Lophopappus Rusby	Asteraceae	x	.	.	x	.	.	.	.	x	x
Lorenzochloa Reeder & C. Reeder	Poaceae	.	.	.	.	.	.	x	.	.	.
Loricaria Wedd.	Asteraceae	x	x	x	x	.	x	x	x	.	.
Lourteigia R.M. King & H. Rob.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Lucilia Cass.	Asteraceae	x	.	x	x	x	x	x	x	.	.
Luciliopsis Wedd.	Asteraceae	.	x	x	.	.	.	.	.	.	x
Lupinus L.	Fabaceae	x	x	x	x	x	x	x	x	x	x
Luzula DC.	Juncaceae	x	x	x	x	x	x	x	x	.	x
Lycianthes (Dunal) Hassl.	Solanaceae	x	.	x	x	x	.	.	.	.	.
Lycium L.	Solanaceae	.	.	.	.	.	.	.	.	.	x
Lycopodiella Holub	Lycopodiaceae	.	.	.	.	.	.	x	x	.	.
Lycopodium L.	Lycopodiaceae	.	x	.	x	x	x	x	x	.	.
Lycurus Kunth	Poaceae	.	x	x	.	.	.	.	x	.	x
Lysimachia L.	Primulaceae	.	.	.	.	.	.	.	x	x	.
Lysipomia Kunth	Campanulaceae	.	.	x	x	x	.	x	x	.	.
Macleania Hook.	Ericaceae	.	.	.	.	.	.	x	x	.	.
Macrocarpaea (Griseb.) Gilg	Gentianaceae	.	.	.	.	.	.	x	x	.	.
Malaxis Sol. ex Sw.	Orchidaceae	.	.	.	x	x	.	x	.	.	.
Mancoa Wedd.	Brassicaceae	x	x	.	x	.	.	.	.	.	x
Margyricarpus Ruiz & Pav.	Rosaceae	.	.	x	x	.	x	.	.	.	.
Marsilea L.	Marsileaceae	.	.	.	.	.	.	.	.	.	x
Masdevallia Ruiz & Pav.	Orchidaceae	.	.	.	x	.	x	x	x	.	.
Mastigostyla I.M. Johnst.	Iridaceae	x	x	.	.	.	.	.	.	x	x
Matucana Britton & Rose	Cactaceae	.	.	.	x	.	x	.	.	.	.
Maxillaria Ruiz & Pav.	Orchidaceae	.	.	.	.	.	.	x	.	.	.
Maytenus Molina	Celastraceae	.	x	.	.	x	.	.	x	.	x
Mediolobivia Backeb.	Cactaceae	.	.	.	.	.	.	.	.	.	x
Melica L.	Poaceae	x	x	.	x	x	x	.	.	.	.
Melinia Decne.	Apocynaceae	.	.	.	.	x	.	.	.	.	.
Melpomene A.R. Sm. & R.C. Moran	Polypodiaceae	x	.	.	x	.	.	x	x	.	.
Menodora Bonpl.	Oleaceae	.	.	.	.	.	.	.	.	.	x
Mentzelia L.	Loasaceae	.	x	.	.	x	.	.	.	.	x
Metastelma R. Br.	Apocynaceae	.	.	.	x	.	.	.	.	.	.
Mezobromelia L.B. Sm.	Bromeliaceae	.	.	.	.	.	.	.	x	.	.
Miconia Ruiz & Pav.	Melastomataceae	.	.	.	x	.	x	x	x	.	.
Microchloa R. Br.	Poaceae	.	.	.	.	.	.	.	.	.	x
Microgramma C. Presl	Polypodiaceae	.	.	.	x	x	.	.	.	.	.
Mikania Willd.	Asteraceae	.	.	.	.	.	.	.	x	.	.
Mimosa L.	Fabaceae	.	.	.	.	.	x	.	.	.	.
Mimulus L.	Phrymaceae	x	x	x	x	x	x	x	.	x	x
Minthostachys (Benth.) Spach	Lamiaceae	.	x	.	.	x	x	.	.	.	.
Minthostachys (Benth.) Spach	Lamiaceae	.	x	x	x	.	.	.	x	.	.
Mirabilis L.	Nyctaginaceae	x	.	.	.	x	.	.	.	.	x
Misbrookea V.A. Funk	Asteraceae	x	x	.	x	x	.	.	.	.	.

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Misopates Raf.	Plantaginaceae	.	x	.	.	.	.	.	.	.	.
Mitracarpus Zucc.	Rubiaceae	.	x	.	.	.	.	.	.	.	x
Mniodes (A. Gray) A. Gray ex Benth. & Hook. f.	Asteraceae	x	x	x	x	x	x	.	.	.	.
Monactis Kunth	Asteraceae	.	.	.	.	.	x	.	x	.	.
Monnina Ruiz & Pav.	Polygalaceae	x	.	x	x	x	x	x	x	.	x
Monochaetum (DC.) Naudin	Melastomataceae	.	.	.	.	.	.	x	.	.	.
Montia L.	Montiaceae	x	x	x	.	.	.	x	.	.	.
Monticalia C. Jeffrey	Asteraceae	.	.	.	.	.	.	.	x	.	.
Montiopsis Kuntze	Montiaceae	x	x	.	.	.	.	.	.	x	.
Moritzia DC. ex Meisn.	Boraginaceae	.	.	.	.	.	.	x	x	.	.
Moschopsis Phil.	Calyceraceae	.	.	.	.	.	.	.	.	x	x
Mostacillastrum O.E. Schulz	Brassicaceae	x	.	.	.	.	.	.	.	.	.
Muehlenbeckia Meisn.	Polygonaceae	.	x	x	x	x	x	x	x	x	.
Muhlenbergia Schreb.	Poaceae	x	x	x	x	x	x	x	x	.	x
Mulinum Pers.	Apiaceae	.	x	.	.	.	.	.	.	x	x
Munnozia Ruiz & Pav.	Asteraceae	.	.	.	x	.	.	.	x	.	.
Munroa Torr.	Poaceae	.	.	.	.	.	.	.	.	x	x
Mutisia L. f.	Asteraceae	x	x	x	x	x	.	.	.	x	x
Myosotis L.	Boraginaceae	.	x	.	.	.	.	.	.	.	.
Myosuros Adans.	Ranunculaceae	.	.	.	.	.	.	.	.	.	x
Myrcianthes O. Berg	Myrtaceae	.	x	.	.	x	x	.	x	.	.
Myrica L.	Myricaceae	.	x	.	x	.	.	x	.	.	.
Myriophyllum L.	Haloragaceae	.	x	x	x	x	.	x	.	x	.
Myrosmodes Rchb. f.	Orchidaceae	x	x	x	x	.	x	x	x	.	.
Myrrhidendron J.M. Coult. & Rose	Apiaceae	.	.	.	.	.	.	x	.	.	.
Myrsine L.	Primulaceae	.	x	.	x	x	.	.	x	.	.
Myrteola O. Berg	Myrtaceae	.	.	.	.	.	.	x	x	.	.
Nama L.	Boraginaceae	x	.	.	.	.	.	.	.	.	.
Nardophyllum (Hook. & Arn.) Hook. & Arn.	Asteraceae	.	.	.	.	.	.	.	.	.	x
Nasa Weigend	Loasaceae	.	.	.	.	.	.	.	x	.	.
Nassauvia Comm. ex Juss.	Asteraceae	.	.	.	.	.	.	.	.	.	x
Nassella (Trin.) E. Desv.	Poaceae	x	x	x	x	x	x	.	.	.	x
Nastanthus Miers	Calyceraceae	.	.	.	.	.	.	.	.	x	x
Neocracca Kuntze	Fabaceae	.	.	.	.	.	.	.	.	.	x
Neocuatrecasia R.M. King & H. Rob.	Asteraceae	.	.	x	.	x	.	.	.	.	.
Neoporteria Britton & Rose	Cactaceae	.	.	.	.	.	.	.	.	x	.
Neowerdermannia Frič	Cactaceae	x	.	.	.	.	.	.	.	x	x
Nephopteris Lellinger	Pteridaceae	.	.	.	.	.	.	x	.	.	.
Nertera Banks & Sol. ex Gaertn.	Rubiaceae	.	x	.	.	x	x	x	x	x	x
Neuontobotrys O.E. Schulz	Brassicaceae	.	.	.	.	.	.	.	.	x	.
Nicandra Adans.	Solanaceae	.	x	.	.	.	.	.	.	.	.
Nicotiana L.	Solanaceae	x	x	x	x	x	.	.	.	x	x
Nierembergia Ruiz & Pav.	Solanaceae	.	x	.	.	.	x	x	.	.	x
Niphidium J. Sm.	Polypodiaceae	.	x	.	.	x	.	.	x	.	.
Niphogeton Schltdl.	Apiaceae	x	x	x	x	x	.	x	x	.	.
Nitrophila S. Watson	Amaranthaceae	.	.	.	.	.	.	.	.	.	x
Nothoscordum Kunth	Amaryllidaceae	x	.	.	.	x	x	.	.	.	x
Noticastrum DC.	Asteraceae	.	x	x	x	x	x	x	.	.	x
Nototriche Turcz.	Malvaceae	x	x	x	x	.	.	.	.	x	x
Novenia S.E. Freire	Asteraceae	.	x	x	x	x	x	.	.	.	.
Odontoglossum Kunth	Orchidaceae	.	x	.	x	.	x	x	x	.	.
Oenothera L.	Onagraceae	x	x	x	x	x	x	x	x	.	x
Oligactis (Kunth) Cass.	Asteraceae	.	.	.	.	.	.	x	x	.	.
Olsynium Raf.	Iridaceae	x	x	.	.	.	.	.	.	.	.

Genera	Family \ Geogr. area	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Ombrophytum Poepp. ex Endl.	Balanophoraceae	.	.	.	.	.	.	.	.	x	x
Oncidium Sw.	Orchidaceae	.	x	.	.	x	x	x	x	.	.
Onoseris Willd.	Asteraceae	.	.	.	x	x	.	.	.	.	.
Ophioglossum L.	Ophioglossaceae	x	x	x	x	x	.	x	x	.	x
Ophryosporus Meyen	Asteraceae	x	x	.	x	x	.	.	.	x	.
Opuntia Mill.	Cactaceae	x	x	x	x	x	x	.	.	x	x
Oreanthes Benth.	Ericaceae	.	.	.	.	.	.	.	x	.	.
Oreithales Schltdl.	Ranunculaceae	.	x	x	.	x	x	.	.	.	.
Oreobolopsis T. Koyama & Guagl.	Cyperaceae	.	.	x	x	.	.	.	.	.	.
Oreobolus R. Br.	Cyperaceae	.	x	.	x	.	x	x	x	.	.
Oreocallis R. Br.	Proteaceae	.	.	.	x	.	x	.	.	.	.
Oreocereus (A. Berger) Riccob.	Cactaceae	x	.	.	x	.	.	.	.	x	x
Oreomyrrhis Endl.	Apiaceae	x	x	x	x	x	x	x	x	.	x
Oreopanax Decne. & Planch.	Araliaceae	.	x	.	x	x	x	x	x	.	.
Oritrophium (Kunth) Cuatrec.	Asteraceae	x	x	x	x	.	x	x	x	.	.
Oroya Britton & Rose	Cactaceae	.	.	x	x	.	.	.	.	.	.
Orthrosanthus Sweet	Iridaceae	.	.	x	x	.	x	x	x	.	.
Oryzopsis Michx.	Poaceae	.	.	.	.	.	.	.	.	.	x
Otholobium C.H. Stirt.	Fabaceae	x	x	x	x	x	x	.	x	x	.
Ourisia Comm. ex Juss.	Plantaginaceae	x	x	.	x	x	.	x	x	x	.
Oxalis L.	Oxalidaceae	x	x	x	x	x	x	x	x	x	x
Oxybaphus L'Hér. ex Willd.	Nyctaginaceae	.	.	.	.	.	.	.	.	x	x
Oxychloe Phil.	Juncaceae	x	x	.	.	.	.	.	.	x	x
Oxylobus (DC.) Moc. ex A. Gray	Asteraceae	.	.	.	.	.	.	x	.	.	.
Oziroe Raf.	Asparagaceae	x	.	.	.	.	.	.	.	.	.
Pachyphyllum Kunth	Orchidaceae	.	x	.	.	x	x	x	x	.	.
Paepalanthus Mart.	Eriocaulaceae	.	.	.	.	x	x	x	x	.	.
Palicourea Aubl.	Rubiaceae	.	.	.	.	.	.	x	x	.	.
Panicum L.	Poaceae	.	.	.	.	.	.	.	.	.	x
Pappobolus S.F. Blake	Asteraceae	.	.	.	x	.	x	x	.	.	.
Pappophorum Schreb.	Poaceae	.	.	.	.	.	.	.	.	.	x
Paramiflos Cuatrec.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Paranephelius Poepp.	Asteraceae	.	x	x	x	x	x	.	.	.	.
Parastrephia Nutt.	Asteraceae	x	x	.	.	x	.	.	.	x	x
Parietaria L.	Urticaceae	x	x	.	.	.	.	.	x	.	.
Parodia Speg.	Cactaceae	.	x	.	.	.	.	.	.	.	x
Parodiodoxa O.E. Schulz	Brassicaceae	.	.	.	.	.	.	.	.	.	x
Paronychia Mill.	Caryophyllaceae	x	x	x	x	x	x	x	x	x	x
Parthenium L.	Asteraceae	.	x	.	.	.	.	.	x	.	x
Paspalum L.	Poaceae	.	x	x	x	x	x	x	x	.	.
Passiflora L.	Passifloraceae	x	x	x	x	x	x	.	x	.	.
Pecluma M.G. Price	Polypodiaceae	.	x	.	x	x	x	x	x	.	.
Pectis L.	Asteraceae	.	.	.	.	.	.	.	.	.	x
Pectocarya DC. ex Meisn.	Boraginaceae	x	.	.	.	.	.	.	.	.	x
Pedicularis	Orobanchaceae	.	.	.	.	.	.	.	x	.	.
Pelexia Poit. ex Lindl.	Orchidaceae	.	x	.	.	x	.	.	x	.	.
Pellaea Link	Pteridaceae	x	x	x	x	x	x	x	x	x	x
Pennellia Nieuwl.	Brassicaceae	.	.	.	.	.	.	.	.	.	x
Pentacalia Cass.	Asteraceae	.	.	.	x	x	x	x	x	.	.
Peperomia Ruiz & Pav.	Piperaceae	x	x	x	x	x	x	x	x	.	x
Perezia Lag.	Asteraceae	x	x	x	x	x	x	.	.	x	x
Pernettya Gaudich.	Ericaceae	.	x	x	x	x	x	x	x	.	x
Persea Mill.	Lauraceae	.	.	.	.	.	.	.	x	.	.
Phacelia Juss.	Boraginaceae	x	x	.	x	x	.	.	.	x	x

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Phlegmariurus Holub	Lycopodiaceae	.	.	.	.	.	.	x	.	.	.
Phlox L.	Polemoniaceae	x	x	x	x	.	.	.	.	x	x
Phrygilanthus Eichler	Loranthaceae	.	x	.	.	x	.	.	.	x	x
Phyla Lour.	Verbenaceae	x	.	.	.	.	.	.	.	.	.
Phyllanthus L.	Phyllanthaceae	.	x	.	.	.	x	x	x	.	.
Phylloscirpus C.B. Clarke	Cyperaceae	x	x	.	.	.	.	x	x	x	.
Physalis L.	Solanaceae	.	x	x	x	x	x	x	x	x	x
Phytolacca Hill	Phytolaccaceae	.	.	.	x	x	.	x	x	x	.
Picrosia D. Don	Asteraceae	.	x	.	.	.	x	.	.	.	.
Pilea Lindl.	Urticaceae	.	x	x	x	x	x	x	x	x	x
Pilularia L.	Marsileaceae	.	.	.	.	.	.	x	.	.	.
Pineda Ruiz & Pav.	Salicaceae	.	x	.	x	x	.	.	.	.	.
Pinguicula L.	Lentibulariaceae	.	x	.	.	.	x	x	x	x	.
Piper L.	Piperaceae	.	x	x	x	x	x	x	x	.	x
Piptochaetium J. Presl	Poaceae	.	x	x	x	x	x	x	x	x	x
Pitcairnia L'Hér.	Bromeliaceae	.	x	x	x	x	x	x	x	.	.
Plagiobothrys Fisch. & C.A. Mey.	Boraginaceae	x	x	x	x	x	.	.	.	x	x
Plagiocheilus Arn. ex DC.	Asteraceae	x	x	.	x	.	.	x	x	.	.
Plagiogyria (Kunze) Mett.	Plagiogyriaceae	.	x	.	x	.	.	.	x	.	.
Plantago L.	Plantaginaceae	x	x	x	x	x	x	x	x	x	x
Plazia Ruiz & Pav.	Asteraceae	x	x	.	.	.	.	.	.	x	x
Pleopeltis Humb. & Bonpl. ex Willd.	Polypodiaceae	.	x	.	.	.	x	.	x	.	.
Plettkea Mattf.	Caryophyllaceae	.	.	x	x	.	.	.	x	.	.
Pleurothallis R. Br.	Orchidaceae	.	x	.	x	.	x	x	x	.	.
Plutarchia A.C. Sm.	Ericaceae	.	.	.	.	.	.	x	.	.	.
Poa L.	Poaceae	x	x	x	x	x	x	x	x	x	x
Poidium Nees	Poaceae	.	x	.	.	.	x	.	.	.	.
Polyachyrus Lag.	Asteraceae	x	.	.	.	.	.	.	.	x	.
Polygala L.	Polygalaceae	.	x	.	x	x	x	x	x	.	x
Polygonum L.	Polygonaceae	.	x	.	.	x	x	.	x	x	x
Polylepis Ruiz & Pav.	Rosaceae	x	x	x	x	x	x	x	x	x	x
Polymnia Kalm	Asteraceae	.	x	.	x	.	.	.	x	.	.
Polypodium L.	Polypodiaceae	x	x	.	x	x	x	x	.	.	.
Polypogon Desf.	Poaceae	x	x	x	x	x	x	.	x	x	.
Polypsecadium O.E. Schulz	Brassicaceae	.	.	.	.	x	.	.	x	.	x
Polystichum Roth	Dryopteridaceae	x	x	x	x	x	.	x	x	.	x
Porodittia G. Don	Calceolariaceae	.	.	.	x	.	.	.	.	.	.
Porophyllum Guett.	Asteraceae	.	x	.	.	.	.	.	x	.	x
Portulaca L.	Portulacaceae	x	x	.	x	.	.	.	x	x	x
Potamogeton L.	Potamogetonaceae	.	x	x	x	x	x	x	x	x	x
Potentilla L.	Rosaceae	.	.	.	x	.	x	x	.	.	.
Prosopis L.	Fabaceae	.	x	.	.	.	.	.	.	x	x
Proustia Lag.	Asteraceae	x	x	.	.	x	.	.	.	x	x
Psammisia Klotzsch	Ericaceae	.	x	x	.	x	x	x	x	.	.
Psilactis A. Gray	Asteraceae	.	.	x	.	.	.	.	.	.	.
Psychotria L.	Rubiaceae	.	x	x	x	x	x	x	x	.	x
Pterichis Lindl.	Orchidaceae	.	x	.	x	.	.	x	x	.	.
Pteridium Gled. ex Scop.	Dennstaedtiaceae	.	x	x	x	x	x	x	x	.	x
Pteris L.	Pteridaceae	.	x	x	x	x	x	x	x	.	x
Puccinellia Parl.	Poaceae	.	x	.	.	.	.	.	.	x	x
Purpurella Naudin	Melastomataceae	.	.	.	.	.	.	x	.	.	.
Puya Molina	Bromeliaceae	x	x	x	x	x	x	x	x	x	x
Pycnophyllum Remy	Caryophyllaceae	x	x	x	x	x	x	.	.	x	x
Quinchamalium Molina	Schoepfiaceae	x	x	x	x	x	x	.	.	x	x

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Ranunculus L.	Ranunculaceae	x	x	x	x	x	x	x	x	x	x
Rapanea Aubl.	Primulaceae	.	.	.	.	.	.	x	.	.	.
Rebutia K. Schum.	Cactaceae	.	x	.	.	.	.	.	.	.	x
Reyesia Gay	Solanaceae	.	.	.	.	.	.	.	.	x	.
Rhizocephalum Wedd.	Campanulaceae	.	.	.	.	.	.	x	.	.	.
Rhynchospora Vahl	Cyperaceae	x	x	x	.	x	x	x	x	.	x
Ribes L.	Grossulariaceae	x	x	x	x	x	x	x	x	.	.
Rorippa Scop.	Brassicaceae	.	x	x	x	x	x	.	x	.	x
Rostkovia Desv.	Juncaceae	.	.	.	.	.	.	.	x	.	.
Rubus L.	Rosaceae	.	x	x	x	x	x	x	x	x	x
Rumex L.	Polygonaceae	x	x	x	x	x	x	x	x	x	x
Ruppia L.	Ruppiaceae	.	.	.	.	x	.	.	.	x	x
Sabazia Cass.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Sagina L.	Caryophyllaceae	.	x	x	x	x	x	x	x	x	x
Salicornia L.	Amaranthaceae	x	.	.	.	.	.	.	x	x	x
Salpichroa Miers	Solanaceae	x	x	x	x	x	x	.	x	x	x
Salpiglossis Ruiz & Pav.	Solanaceae	.	.	.	.	.	.	.	.	x	.
Salvia L.	Lamiaceae	x	x	x	x	x	x	x	x	x	x
Sambucus L.	Adoxaceae	.	x	.	x	x	x	.	x	.	x
Saracha Ruiz & Pav.	Solanaceae	.	x	.	x	.	.	.	x	.	.
Satureja L.	Lamiaceae	x	x	x	x	x	x	x	x	x	x
Saxifraga L.	Saxifragaceae	x	x	x	x	x	x	x	x	x	x
Scaphosepalum Pfitzer	Orchidaceae	.	.	.	.	.	.	x	.	.	.
Schinus L.	Anacardiaceae	x	x	.	x	x	x	.	.	x	x
Schizachyrium Nees	Poaceae	.	x	.	x	.	x	.	x	.	x
Schkuhria Roth	Asteraceae	x	x	.	.	x	.	.	.	x	x
Schoenoplectus (Rchb.) Palla	Cyperaceae	x	x	.	x	.	x	.	.	x	.
Scirpus L.	Cyperaceae	.	x	x	x	x	x	x	.	x	x
Sclerophylax Miers	Solanaceae	.	.	.	.	.	.	.	.	.	x
Scrobicaria Cass.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Scutellaria L.	Lamiaceae	.	x	x	x	x	x	x	x	x	x
Sebastiania Spreng.	Euphorbiaceae	.	x	.	x	x	.	.	.	.	x
Sedum L.	Crassulaceae	x	x	.	x	.	x	.	x	.	x
Selaginella P. Beauv.	Selaginellaceae	.	x	x	x	x	x	x	x	.	x
Selloa Kunth	Asteraceae	.	.	.	.	.	.	x	.	.	.
Semiramisia Klotzsch	Ericaceae	.	.	.	.	.	.	.	x	.	.
Senecio L.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Senna Mill.	Fabaceae	.	x	x	x	x	x	x	x	x	x
Sericotheca Raf.	Rosaceae	.	.	.	.	.	.	x	.	.	.
Serjania Mill.	Sapindaceae	.	x	x	x	x	x	x	x	.	x
Sesbania Adans.	Fabaceae	.	x	.	.	.	x	x	x	x	x
Sessea Ruiz & Pav.	Solanaceae	.	x	x	.	x	x	x	x	.	.
Setaria P. Beauv.	Poaceae	.	x	x	x	x	x	x	x	x	x
Sherardia L.	Rubiaceae	.	x	x	.	.	x	x	x	x	x
Sibthorpia L.	Plantaginaceae	.	x	x	x	x	x	x	x	.	x
Sicyos L.	Cucurbitaceae	x	x	x	x	x	x	x	x	x	x
Sida L.	Malvaceae	.	x	x	x	x	x	x	x	x	x
Siegesbeckia L.	Asteraceae	.	x	.	x	x	.	x	.	.	.
Silene L.	Caryophyllaceae	x	x	x	x	x	.	.	x	x	x
Siphocampylus Pohl	Campanulaceae	.	x	x	x	x	x	x	x	x	x
Sisymbrium L.	Brassicaceae	x	x	x	x	x	.	.	.	x	x
Sisyrinchium L.	Iridaceae	x	x	x	x	x	x	x	x	x	x
Solanum L.	Solanaceae	x	x	x	x	x	x	x	x	x	x
Soliva Ruiz & Pav.	Asteraceae	.	x	.	x	.	.	.	x	.	.

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Sorghastrum Nash	Poaceae	.	x	.	.	x	x	.	x	x	x
Spathantheum Schott	Araceae	.	x	.	.	x	.	.	.	.	x
Spergula L.	Caryophyllaceae	.	x	.	x	.	x	.	.	x	.
Spergularia (Pers.) J. Presl & C. Presl	Caryophyllaceae	x	x	.	.	x	.	.	x	x	x
Spermacoce L.	Rubiaceae	.	x	.	x	x	x	x	x	.	x
Sphacele Benth.	Lamiaceae	.	x	x	x	x	x	x	x	x	x
Sphyrospermum Poepp. & Endl.	Ericaceae	.	x	.	.	x	x	x	x	.	.
Spilanthes Jacq.	Asteraceae	.	.	.	.	.	.	x	.	.	x
Sporobolus R. Br.	Poaceae	x	x	x	x	x	x	x	x	x	x
Stachys L.	Lamiaceae	x	.	x	x	x	x	x	x	x	x
Steiractinia S.F. Blake	Asteraceae	.	.	.	.	.	.	x	.	.	.
Stelis Sw.	Orchidaceae	.	.	.	x	x	.	.	x	.	.
Stellaria L.	Caryophyllaceae	x	x	x	x	x	x	x	x	x	x
Stemodia L.	Plantaginaceae	.	x	x	.	x	.	.	x	.	.
Stenandrium Nees	Acanthaceae	.	x	.	.	x	.	.	x	.	x
Stenomesson Herb.	Amaryllidaceae	x	x	x	x	x	x	.	x	x	.
Stenorrhynchos Rich. ex Spreng.	Orchidaceae	.	.	.	.	.	.	x	x	.	.
Stevia Cav.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Sticherus C. Presl	Gleicheniaceae	.	.	.	.	.	.	.	x	.	.
Stipa L.	Poaceae	x	x	x	x	x	x	x	x	x	x
Stuckertiella Beauverd	Asteraceae	.	x	x	x	x	x	.	x	x	x
Styloceras Kunth ex A. Juss.	Buxaceae	.	x	.	.	x	.	.	x	.	.
Suaeda Forssk. ex J.F. Gmel.	Amaranthaceae	.	.	.	.	.	.	.	.	x	x
Swallenochloa McClure	Poaceae	.	.	.	.	.	.	x	.	.	.
Symbolanthus G. Don	Gentianaceae	.	.	.	.	.	.	.	x	.	.
Symplocos Jacq.	Symplocaceae	.	x	x	x	x	x	x	x	.	x
Tagetes L.	Asteraceae	x	x	x	x	x	x	x	x	x	x
Tamania Cuatrec.	Asteraceae	.	.	.	.	.	.	x	.	.	.
Tarasa Phil.	Malvaceae	x	x	x	x	x	.	.	.	x	x
Tecoma Juss.	Bignoniaceae	.	x	x	x	x	x	.	.	x	x
Tephrocactus Lem.	Cactaceae	x	x	x	x	.	.	.	.	x	x
Ternstroemia Mutis ex L. f.	Pentaphylacaceae	.	x	.	.	x	x	x	x	.	.
Terpsichore A.R. Sm.	Polypodiaceae	.	x	x	x	x	x	x	x	.	x
Tessaria Ruiz & Pav.	Asteraceae	.	x	.	x	x	x	.	x	x	x
Tetraglochin Poepp.	Rosaceae	x	x	x	x	x	x	.	.	x	x
Thalictrum L.	Ranunculaceae	.	x	x	x	x	x	x	x	.	x
Thelypteris Schmidel	Thelypteridaceae	x	x	x	x	x	x	x	x	.	.
Themistoclesia Klotzsch	Ericaceae	.	.	.	.	.	.	.	x	.	.
Thibaudia Ruiz & Pav. ex J. St.-Hil.	Ericaceae	.	x	x	.	x	x	x	x	.	.
Thuidium Schimp.	Thuidiaceae	.	x	x	x	x	x	x	x	x	x
Tibouchina Aubl.	Melastomataceae	.	x	x	x	x	x	x	x	.	x
Tigridia Juss.	Iridaceae	.	x	.	x	x	.	x	x	x	.
Tillandsia L.	Bromeliaceae	x	x	x	x	x	x	x	x	x	x
Tiquilia Pers.	Boraginaceae	.	x	.	x	.	.	.	x	x	x
Tofieldia Huds.	Tofieldiaceae	.	.	.	.	.	.	x	.	.	.
Tortella (Lindb.) Limpr.	Pottiaceae	.	x	.	.	.	x	.	.	x	x
Trachypogon Nees	Poaceae	.	x	.	.	.	x	.	.	.	.
Tragus Haller	Poaceae	.	.	.	x	.	.	.	x	.	x
Trechonaetes Miers	Solanaceae	.	.	.	.	.	.	.	.	x	x
Tribulus L.	Zygophyllaceae	.	x	.	.	x	x	.	x	.	x
Trichlora Baker	Amaryllidaceae	.	.	.	x	.	.	.	.	.	.
Trichloris E. Fourn. ex Benth.	Poaceae	.	.	.	.	.	x	.	x	.	x
Trichoceros Kunth	Orchidaceae	.	x	x	x	x	x	x	x	.	.
Trichocline Cass.	Asteraceae	.	x	.	.	.	x	.	x	x	x

Genera	**Family \ Geogr. area**	MOQ	BOL	JUN	ANC	CUS	CAJ	COL	ECU	CHI	ARG
Trichomanes L.	Hymenophyllaceae	.	x	x	.	x	x	x	x	x	x
Trichophorum Pers.	Cyperaceae	x	x	x	x	x	.	.	.	x	x
Trichosalpinx Luer	Orchidaceae	.	.	.	.	.	.	.	x	.	.
Tridax L.	Asteraceae	.	x	.	.	.	x	.	.	.	.
Tridens Roem. & Schult.	Poaceae	.	.	.	.	.	.	.	.	.	x
Trifolium L.	Fabaceae	x	x	x	x	x	x	x	x	.	x
Triglochin L.	Juncaginaceae	x	x	.	.	x	.	.	.	x	x
Triniochloa Hitchc.	Poaceae	x	x	.	.	x	.	x	x	.	.
Tripodanthus (Eichler) Tiegh.	Loranthaceae	.	x	.	x	x	x	.	x	.	x
Tripogandra Raf.	Commelinaceae	.	x	x	.	x	x	x	x	.	x
Trisetum Pers.	Poaceae	x	x	x	x	x	x	x	x	x	x
Tristerix Mart.	Loranthaceae	.	x	x	x	x	x	.	x	x	x
Trixis P. Browne	Asteraceae	.	x	.	x	x	x	x	x	x	x
Tropaeolum L.	Tropaeolaceae	x	x	x	x	x	x	x	x	x	x
Tunilla D.R. Hunt & Iliff	Cactaceae	x	x	.	.	.	.	.	.	.	.
Ugni Turcz.	Myrtaceae	.	x	.	.	.	.	x	x	.	.
Ullucus Caldas	Basellaceae	x	x	x	x	x	.	.	.	.	x
Uncinia Pers.	Cyperaceae	.	x	x	.	x	x	x	x	x	x
Urbania Phil.	Verbenaceae	.	.	.	.	.	.	.	.	x	.
Urmenetea hil.	Asteraceae	.	.	.	.	.	.	.	.	x	x
Urocarpidium Ulbr.	Malvaceae	x	x	x	x	.	x	.	x	x	x
Urtica L.	Urticaceae	x	x	x	x	x	x	x	x	x	x
Utricularia L.	Lentibulariaceae	.	x	x	.	x	x	x	x	x	x
Vaccinium L.	Ericaceae	.	x	x	x	x	x	x	x	.	x
Valeriana L.	Caprifoliaceae	x	x	x	x	x	x	x	x	x	x
Vallea Mutis ex L. f.	Elaeocarpaceae	.	x	x	x	x	x	x	x	.	x
Vasquezia Phil.	Asteraceae	x	x	x	x	x	x	x	x	x	.
Verbena L.	Verbenaceae	x	x	x	x	x	x	x	x	x	x
Verbesina L.	Asteraceae	.	x	x	x	x	x	x	x	x	x
Vicia L.	Fabaceae	x	x	x	x	x	x	x	x	x	x
Viguiera Kunth	Asteraceae	x	x	x	x	x	x	x	x	x	x
Viola L.	Violaceae	x	x	x	x	x	x	x	x	x	x
Vulpia C.C. Gmel.	Poaceae	x	x	x	x	x	x	x	x	x	x
Wahlenbergia Schrad. ex Roth	Campanulaceae	x	x	x	x	x	x	.	x	x	x
Weberbauera Gilg & Muschl.	Brassicaceae	x	x	x	x	x	x	.	.	x	x
Weinmannia L.	Cunoniaceae	.	x	x	x	x	x	x	x	x	x
Werneria Kunth	Asteraceae	x	x	x	x	x	x	x	x	x	x
Woodsia R. Br.	Woodsiaceae	x	x	x	x	x	x	x	x	x	x
Xanthium L.	Asteraceae	x	x	.	x	x	x	x	x	x	x
Xenophyllum V.A. Funk	Asteraceae	x	x	.	x	x	x	x	x	x	x
Xiphopteris Kaulf.	Polypodiaceae	.	.	.	.	.	.	x	.	.	.
Xyris Gronov.	Xyridaceae	.	x	x	.	x	x	x	x	.	x
Zameioscirpus Dhooge & Goetgh.	Cyperaceae	x	x	.	x	.	.	.	.	x	x
Zannichellia L.	Potamogetonaceae	.	x	x	x	x	.	.	.	x	x
Zephyranthes Herb.	Amaryllidaceae	x	x	.	.	x	.	.	x	x	x
Zinnia L.	Asteraceae	.	x	.	.	x	x	x	x	.	x

CHAPTER 7

Taxonomic publications

Paronychia ubinensis (Caryophyllaceae): A new species from South Peru.
Published in Phytotaxa (2013) 124(1): 50–54.

Three new caespitose species of *Senecio* (Asteraceae: Senecioneae) from South Peru.
Published in Phytokeys (2014) 39: 1–17.

Arenaria acaulis (Caryophyllaceae): A new species from South Peru.
Published in Phytotaxa (2015) 220(1): 77–82.

Tigridia arequipensis (Iridaceae: Tigridieae): A new species from South Peru.
Blumea (2016) 61: 4–7.

Paronychia ubinensis (Caryophyllaceae: Paronychioideae) a new species from Moquegua, South Peru

Montesinos-Tubée, D.B.
Phytotaxa (2013) 124(1): 50–54

Abstract

As part of the botanical and phytosociological characterisation of the Moqueguan flora, several Caryophyllaceae were studied. A specimen that was collected from the Ubinas district is named *Paronychia ubinensis* (Caryophyllaceae: Paronychioideae) and described as a new species. This species is compared with its closest relatives *P. andina, P. mandoniana, P. muschleri, P. peruviana* and *P. weberbaueri* from Southern Peru.

Key words: Paronychia ubinensis, Caryophyllaceae, Paronychioideae, new species, Southern Peru

Introduction

Paronychia Miller (Bittrich 1993) consists of approximately 110 species worldwide (Chaudhri 1968, Kool 2012), 11 species and 7 subspecies are recorded from Peru (Macbride 1937; Brako & Zarucchi 1993). During a study on the flora and vegetation of the Andean region of the department of Moquegua in southern Peru, more than 1000 botanical specimens were collected. While identifying these collections several novelties were discovered (Al-Shehbaz & Montesinos 2009, Montesinos-Tubée 2012a). One such species new to science is described here and named *Paronychia ubinensis*. This species is similar to *Paronychia andina* A. Gray, *P. mandoniana* Rohrb., *P. muschlerii* Chaudhri, *P. peruviana* Chaudhri and *P. weberbaueri* Chaudhri in habit and lifeform characters, but differs in leaf and flower morphology. In *P. ubinensis* the leaves are much shorter, the ciliate hairs on the leaf lamina and margins are absent, the ovary is shorter and the stigma is reduced to <0.1 mm in length.

Results

Paronychia ubinensis Montesinos, spec. nov.
TYPE:-PERU. Moquegua Department: General Sánchez Cerro Province, Ubinas District: Punku near Tassa locality,
16°10’30” S, 70°42’21” W. 4030 m, 6 April 2012, Montesinos 3698 (holotype WAG!, isotype USM).
Additional specimens examined: PERU, Moquegua Department, General Sánchez Cerro Province, Ubinas District: Roadside, Querala-Patune, 4340 m, 1 June 2011, Montesinos 3164 (USM). PERU, Moquegua Department, General Sánchez Cerro Province, Yunga District: Sura slopes, 4500 m, 28 March 2013, Montesinos 4049 (USM, CUZ, HSP).

Diagnosis: Herba perennis, 2–4 cm longa, folia relinquit subterminale glomerulus; bracteae oblongae ovatis; petalis obscure viridis colorem.

Description: Perennial herb with stem woody and branched at the base, decumbent, caespitose, densely congested and imbricate, forming pulvinate tufts, 2–4 cm long, with internodes <0.5 mm long. Leaves disposed in subterminal glomerules. Leaves brown red to lilac red, stiff, linear to narrowly elliptic, 1.8–2.4 mm × 0.6–0.9 mm, apex acute, with translucid, 0.1–0.2 mm stout mucro (brown at the base) with few minute bristle hairs at the tip; margin glabrous and slightly folded, the base of the leaves deep red or pale purple, always darker than the lamina; stipules oblong-lanceolate, 1.8–2.2 mm × 0.6–1.0 mm, mostly equalling the leaves, tip aristate to acuminate, margin and tip with few minute bristle hairs, midrib with more bristle hairs than the lamina. Leaves subglabrous, with few minute hirtella on the mucro. Bracts oblong-ovate, 1.2–2.0 mm × 0.8–1.5 mm, slightly obtuse, with minute hirtella on margins and tip. Flowers few, 1.9–2.2 mm

× 0.9–1.2 mm, glabrous and urceolate; receptacle ovoid, whitish, 0.8–1 mm × 0.6–0.8 mm; sepals ovate, white, scarious, 1.6–1.8 mm × 0.8–1.4 mm, margins with <0.1 mm long white bristle hairs; petals dark red to purple, concave, 0.2–0.4 mm × 0.1–0.2 mm, urceolate, glabrous, base pale green; filaments 0.1–0.3 mm long; anthers 0.1–0.2 mm × 0.05–0.1 mm and pale green; ovary oblong, pale w hite, 0.6–0.8 × 0.6–0.8 mm ; sty le <0.1 mm long, stigma indistinctive. Fruit oblong-ovoid, 1–1.2 mm long, smooth, pale brown; seed c. 0.8–1 mm, subglobose to ovoid.

Ecology and distribution: *Paronychia ubinensis* grows mostly on rocky slopes and plateaus with bare soils and is associated with chasmophyte vegetation. The plant was found at elevations of 4030–4500 m. This species is endemic to Peru and is known thus far only from two collections from Moquegua.

Comparison: *Paronychia ubinensis* is closely related to the Andean *Paronychia* complex (Chaudhri 1968, MacBride 1937, Alvarez 2010, Kool 2012). The geographical parameters and habitats of *Paronychia andina* A. Gray, *P. mandoniana* Rohrb., *P. muschlerii* Chaudhri, *P. peruviana* Chaudhri and *P. weberbaueri* Chaudhri are similar to the newly described species. However, these species differ in morphological characteristics, including leaves, flowers and ovary. Numerous herbarium specimens were examined from USM, HUSA, MO, F, WAG and L. None of the described Andean species of *Paronychia* has internodes shorter than 0.5 mm, the leaf shape linear to narrowly elliptic and size shorter than 2.2 mm, the sepals larger than 1.6 mm and the ovary not larger than 0.8 mm, all characters in *P. ubinensis*. Therefore, *P. ubinensis* has the shortest leaf size and larger ovary size of any known Andean Paronychia species. Another important parameter is the absence of pubescence and bristle hairs on the leaves of *P. ubinensis*. Trichomes are only present on the mucro; as opposed to the related Paronychia species, where pubescence in leaves and leaf indument is common.

Paronychia ubinensis was also compared with the *Paronychia* species occurring in the Bolivian and Chilean Andes, with which significant morphological and geographical differences were found. For instance, *P. communis* Cambess. (Cambessèdes 1829), *P. chilensis* DC. (Candolle 1828), *P. johnstonii* Chaudhrii (Chaudhri 1968) and *P. setigera* (Gillies) F. Herm (Hermann 1937) have larger leaf size (>5 mm) and longitudinal separation of the glomerules (>1 cm), and form more prostrate plants inhabiting disturbed areas in lower elevation regions. *P. hieronymi* Pax (Pax 1894) forms dense woody stems, its leaf size is larger and has a pubescent surface, and it is restricted to Bolivia and Argentina. *P. microphylla* Phil. (Philippi 1891) is characterized by a shrubby habit with larger leaf size and forms dense green glomerules, with a flower size larger than 4 mm. Therefore, *Paronychia ubinensis* can be classified as one of the smallest species from the Andean group.

According to Alvarez (2010), the genus *Paronychia* is polyphyletic and *Paronychia andina* and *Paronychia weberbaueri* form a clade. It is unlikely that the Andean Paronychia species form a monophyletic group (pers. comm. A. Kool).

Etymology: The specific epithet of the new species refers to the endemism in the Ubinas district, in the Moquegua department, southern Peru.

Table 1. Morphological comparison of *Paronychia ubinensis, P. andina, P. mandoniana, P. muschleri, P. peruviana* and *P. weberbaueri.*

Characters	*P. andina*	*P. mandoniana*	*P. muschleri*	*P. peruviana*	*P. ubinensis*	*P. weberbaueri*
Habit	pulvinate perennial herb	perennial herb, postrate to suberect	perennial herb	perennial herb, small and compact	perennial herb, branched at base	perennial herb, ascending or suberect
Glomerules	terminal, subterminal	dense, terminal-subterminal, 4-7 mm	stems prostrate, congested	suberect, 3.5-7.0 cm, ramified	dense, congested, imbricate	terminal
Internodes	glabrous, 1-2 mm	short, 1-5 mm	5-9 mm, pubescent to glabrescent with age	6 mm, oblong to ovate-lanceolate	<0.5 mm	1-3 mm, puberulous, reddish with age
Leaf shape	elliptic-oblong to ovate	lanceolate	obovate-oblanceolate to narrow elliptic-oblong	elliptic, oblong to ovate-lanceolate	linear to narrowly elliptic	elliptic oblong to ovate, concave
Leaf size (mm)	2.5-4 × 1.2-2	3-6 × 0.7-1.2	5-9 × 1.5-2.2	4-6 × 1.2-2.2	1.8-2.2 × 0.6-1.0	2.7-3.5 × 2-2.5
Leaf indument	glabrous or puberulous in the under side	scabrous-pubescent to puberulous	glabrous or sparsely pubescent (ada×ial)	spare or subglabrus, ciliata on margins	glabrous, only with minute hirtella in mucro	hirtellous on both sides, margin sligthly hirsute
Stipules	ovate to oblong, 2-3(-4) × 1.5-2(-2.5) mm	narrow, ovate-lanceolate. 4 mm	ovate-lanceolate	ovate or suboblong, 3.5 mm	oblong to sub oblong, 1-8-2.2 × 0.6-1.0 mm	broadly oval-oblong 3.8 × 2.7 mm
Flower size (mm)	(2-)2.2-2.5(-3.2)	1.7-2	4-5	(2.2-) 2.4-3.0	1.9-2.2 × 0.9-1.2	2.2-2.3
Sepals	oblong, 1.3-1.5(-2) × 0.5-0.7 mm	oblong to lanceolate oblong 1-1.2 mm	oblong to ovate-oblong, 0.6-0.7 × 0.5 mm	pubescent, oblong, (1.2-) 1.4 mm	ovate, scarious, 1.6-1.8 × 0.8-1.4	oblong, obtuse. 1.2-1.4 mm
Ovary	conical, 0.5-0.6 × 0.4-0.5 mm	subsessile, 0.5 × 0.3 mm, ellipsoid	conical-ovoid, 0.5 × 0.4 mm	conicum, 0.7-0.5 mm	oblong, 0.6-0.8 × 0.6-0.8 mm	subquadrangular 0.5 mm in diam.

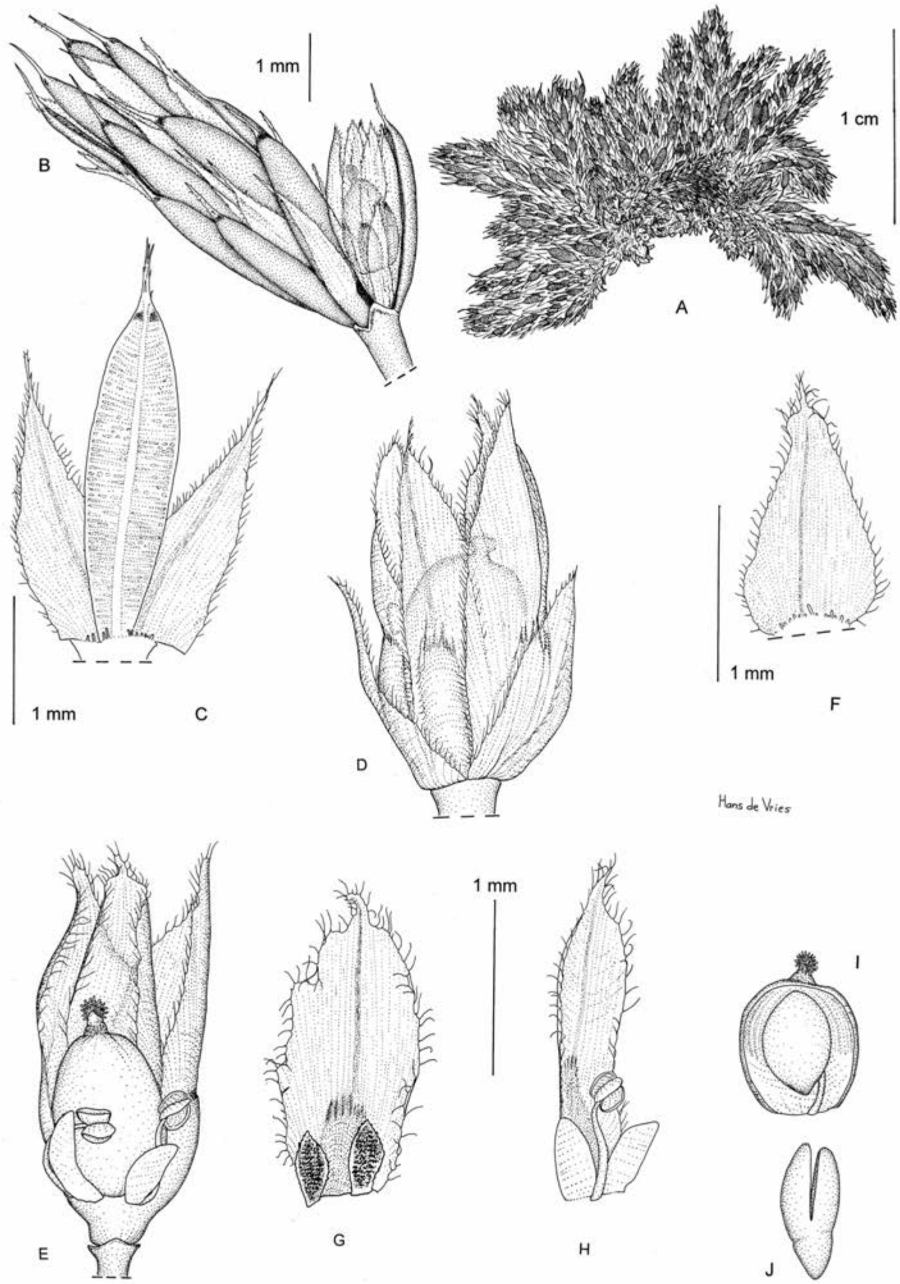


Figure 1. A. Habitus: whole plant; B. Branch with infructescense; C. Leaf with stipules; D. Flowers, with bracts; E. Opened flower (bracts and 2 sepals removed); F. Bract, inside; G. Sepal, inside, with 2 petals; H. Sepal, inside, with 2 petals and 1 anther; I. Ovary, lengthwise section; J. Embryo.

Figure 2. *P. ubinensis*; habit at Punku, Tassa, Ubinas district, General Sánchez Cerro province, 4030 m.

Three new caespitose species of *Senecio* (Asteraceae, Senecioneae) from South Peru

Montesinos-Tubée, D.B.
Phytokeys (2014) 39: 1–17

Abstract

Three new species of the genus *Senecio* (Asteraceae, Senecioneae) belonging to *S.* ser. *Suffruticosi* subser. *Caespitosi* were discovered in the tributaries of the upper Tambo River, Moquegua Department, South Peru. Descriptions, diagnoses and discussions about their distribution, a table with the morphological similarities with other species of *Senecio*, a distribution map, conservation status assessments, and a key to the caespitose Peruvian species of *S.* subser. *Caespitosi* are provided. The new species are *Senecio moqueguensis* Montesinos, sp. nov. (Critically Endangered) which most closely resembles *Senecio pucapampaensis* Beltrán, *Senecio sykorae* Montesinos, sp. nov. (Critically Endangered) which most closely resembles *Senecio gamolepis* Cabrera, and *Senecio tassaensis* Montesinos, sp. nov. (Critically Endangered) which most closely resembles *Senecio moqueguensis* Montesinos.

Key words: Compositae, new species, Senecio subser. Caespitosi, South America, taxonomy

Introduction

Senecio contains about 175 species in Peru (Brako & Zarucchi 1993; Vision & Dillon 1996) including several recently described new species (Beltrán 2009). The genus has 94 species endemic to Peru which have been evaluated and classified according to IUCN criteria (Beltrán et al. 2007). In the Department of Moquegua, 30 species have been recorded (Arakaki & Cano 2003; Montesinos-Tubée 2012a). The species of *Senecio* described here were discovered in the tributaries of the upper Tambo River in southern Peru, an area of extraordinary species richness and a high level of endemism (Montesinos 2011a, 2012a).

Senecio ser. *Suffruticosi* Cabrera accounts for 143 species occurring on the American continent, especially in the Andes and Patagonia (Cabrera 1949, 1985; Cabrera et al. 1999). Cabrera et al. (1999) divided *S.* ser. *Suffruticosi* into five subseries and described it as embracing suffruticose or perennial herbs, glabrous or glandulose, with entire leaves which are dentate or, more rarely, incised, involucres discoid, and capitula isomorphic. Among those subseries, *S.* subser. *Caespitosi* Cabrera contains 50 species (Cabrera et al. 1999), of which thirteen occur in Peru at altitudes between 3500 m and 5000 m (Brako & Zaruchi 1993; Beltrán et al. 2007): *S. adenophyllus* Meyen & Walp., *S. algens* Wedd., *S. scorzonerifolius* Meyen & Walp. and *S. trifurcifolius* Hieron. also distributed in northwesternArgentina, Bolivia and north of Chile, *S. danai* A. Gray and *S. pucapampaensis* Beltrán occurring only in central Peru (Beltrán 2007), *S. evacoides* Sch. Bip., *S. expansus* Wedd. and *S. humillimus* Sch. Bip. also distributed in northwestern Argentina and Bolivia, *S. gamolepis* Cabrera, endemic to central and southern Peru, *S. rufescens* DC. distributed from Colombia to northwestern Argentina, *S. repens* Stokes distributed from south Ecuador through Peru and northwestern Bolivia, and *S. vegetus* (Wedd.) Cabrera, also distributed in Bolivia. In *S.* subser. *Caespitosi* plants are characterized as suffruticose (or herbaceous), glabrous or glandulose; leaves entire, dentate or, more rarely, incised; capitula discoid, medium or small; and flowers isomorphic (Cabrera et al. 1999).

Notwithstanding the progress in taxonomical and molecular studies (Nordenstam 1977; Cabrera 1949, 1985; Cabrera et al. 1999; Pelser et al. 2007; Nordenstam et al. 2009), there are more species of the tribe *Senecioneae* occurring in the Andes which remain poorly understood and are awaiting discovery. Intergeneric relationships within Senecioneae are still largely unknown (Pelser et al. 2007); furthermore, the lack of knowledge about generic-level evolutionary relationships in Senecioneae remains the largest taxonomic problem on the way to obtaining a monophyletic delimitation of *Senecio* (Bremer 1994, Pelser et al. 2007). Phylogenetic positions for the members of *S.* subser. *Caespitosi* are still largely unknown, except for *S. algens*, *S. humillimus* and *S. rufescens* (Pelser et al. 2007), of which *S. algens* belongs to the *Aetheolaena involucrata-A. patens* clade and *S. humillimus* and *S. rufescens* to the *Senecio glaber-S donianus* clade. Numerous new collections from Moquegua have been made in recent years (Montesinos-

Tubée 2011a, 2012a). A comparison with herbarium specimens, together with a review of the literature and taxonomic keys, has shown that these collections include three new species of *S.* subser. *Caespitosi* which are described below. These new species were separated from the other species of this subseries on the basis of a set of characters such as habit, the presence or absence of trichomes, flower color, the number of phyllaries and involucral bracts, the involucre length and the achene type (Cabrera 1955, 1985; Cabrera et al. 1999). The new species can be found at elevations above 4500 m as terrestrial plants on bare rocky soils on the summits of high mountains in the north of Moquegua department, where they co-occur with several other acaulescent *Senecioneae* from *S.* subser. *Caespitosi* such as *S. gamolepis*, *S. evacoides*, and *S. algens*.

Methods

Based on morphological characters, an overview of the genus *Senecio* with an emphasis on *S.* subser. *Caespitosi* from Peru and adjacent areas (Ecuador, Bolivia, Argentina and northern Chile) has been prepared, based on Cabrera (1955, 1985) and Cabrera et al. (1999). Since 2009 I have examined more than 450 specimens of *S.* subser. *Caespitosi* housed in Peruvian herbaria (CUZ, HSP, HUPCH, HUSA, MOL, USM), relevant collections from institutions abroad (B, BR, F, L, LPB, MO, P, WAG), and material from my recent fieldwork. Digitised specimens were viewed via online herbarium catalogues (http://tropicos.org and http://fm1.fieldmuseum.org/vrrc/) or via JSTOR (2013). All morphological characters were studied under a NSZ-405 1X-4.5X stereo microscope and an AmScope M100C-LED 40×-1000× compound microscope. The descriptions were made using the terminology presented by Cabrera (1955, 1985), Cabrera et al. (1999), Vision and Dillon (1996), Beltrán (2009), Nordenstam et al. (2009) and Roque et al. (2009). Conservation assessments were undertaken using the IUCN criteria (IUCN 2001).

Taxonomy

***Senecio moqueguensis* Montesinos, sp. nov.**
urn:lsid:ipni.org:names:77140249-1
Figs 1, 4A, 5

Diagnosis: The new species is morphologically similar to *Senecio pucapampaensis* but is clearly distinguished by the leaf lamina oblong-spathulate (vs. cuneiform), leaf surface covered by thin trichomes (vs. glabrous), corolla yellow (vs. white), calycular bracts linear-oblong, 6–9 mm long (vs. linear, 6–7 mm long), and phyllaries 9–12 (vs. 12–14).
Type: PERU. Moquegua Region, General Sánchez Cerro Province, Ubinas District, NW of Tassa, terrestrial on clayey rocky soils on the plateau peaks near Lake Pacosani, elevation 4653 m, 16°06'43"S, 70°44'45"W, 3 April 2009, *Montesinos 2400* (holotype USM!, isotypes MO 2383567, HUPCH 4185, CPUN, WAG 0246107).
Description: *Perennial* herb, rhizomatous, creeping, low-growing, forming mats 2–4 cm tall and up to 60 cm in diam. *Trichomes* glandular, somewhat dense and irregularly distributed, multicellular, whitish transparent, 0.1–0.3 mm long and 0.05–0.1 mm wide and composed of 4–8 subrotund cells (each 30–50 µm long), apical cell rotund. *Stems* 1–3 cm long, often densely branched and leafy in the central part, rooting. *Leaves* cauline, lamina oblongspathulate, 8–12 mm × 1–2.5 mm, sparsely covered by thin trichomes on the margins, lower and upper surfaces except at the base; base truncated, apex subpinnatifid; young leaves dark green with yellowish margins, turning light green-greyish with age. *Synflorescences* of solitary sessile or subsessile terminal capitula. *Capitula* homogamous, discoid. *Involucres* at first broadly cylindrical, gradually turning campanulate with age, ca. 7–10 mm long × 6–8.5 mm wide). *Calycular bracts* linear-oblong (6–9 mm × 1–2.5 mm), whitish green on the surface and whitish along the margins, with scarce trichomes near the midrib and margins, apex dark brown covered with short light-brown trichomes. *Phyllaries* 9–12, connate, 5–8 mm long × 0.7–1.2 mm wide, oblong-lanceolate, covered with thin trichomes sparsely on the surface and densely along the margins, apex greenish grey and dark brown with short white multicellular trichomes. *Florets* 24–28; corolla tubular, abruptly constricted near the base, 5-lobed, each lobe 0.5 mm long, bright yellow, tube 3–5 mm long × 0.8–1 mm wide; anthers linear-lanceolate, 1.5–2.5 mm long, 0.2–0.4 mm wide, ecalcarate, terminal appendages lanceolate, obtuse, margin whitish transparent and becoming yellow towards the centre; style dark yellow, truncate, papillae covering the whole surface of the apex. *Achenes* cylindrical, covered with trichomes, 1.8–2.5 mm long and 0.4–0.8 mm wide, light brown; carpopodium symmetrical in a small ring; pappus of smooth bristles, white, silky, 5–6 mm long, with fine single setulae.
Ecology and distribution: Terrestrial plant on clayey rocky soils on the peaks of the highland summits and grasslands in the north of Moquegua Region, at elevations of ca.

4500 to 4800 m. Co-occurring species include *Azorella compacta* Phil., *Calamagrostis vicunarum* (Wedd.) Pilg., *Pycnophyllum molle* Remy, and *Festuca* spp. Flowers and fruits between March and April.

Etymology: The specific epithet refers to Moquegua, where the only three collections are known from the north of the department.

Additional material examined (paratypes): PERU. Moquegua Region, General Sánchez Cerro Province, Ubinas District, terrestrial on bare clayey soils in the verges of the road east Pillone town, elevation 4584 m, 16°10'02"S, 70°49'56"W, 24 March 2013, *Montesinos 4022* (USM, HUSA). Moquegua Region, General Sánchez Cerro Province, Ubinas District, NW of Tassa, terrestrial on bare clayey soils in the verges of the road to Lake Cochapata, elevation 4687 m, 16°08'56"S, 70°43'0.30"W, 9 December 2013, *Montesinos 4200* (CUZ).

Discussion: A comparison of the material has shown that *S. moqueguensis* is most similar to *S. pucapampaensis* and *S. tassaensis* sp. nov. Together with *S. evacoides*, *S. expansus*, *S. repens* and *S. humillimus*, it forms a coherent morphological and geographical group within *S.* subser. *Caespitosi* which occurs from central Peru to northwest Argentina and is characterized by the presence of trichomes on stems, leaves and involucres. *Senecio moqueguensis* can be distinguished from *S. pucapampaensis* by the dense caespitose mat habit, leaves, calycular bracts, corolla color, involucres and achene morphology as summarized in Table 1. *Senecio moqueguensis* can be distinguished from *S. evacoides*, *S. expansus* and *S. repens* by the habit, density of trichomes, leaf shape and length, as well as by the calycular bracts and phyllary length and form.

Conservation status: Following the criteria and categories of IUCN (2001), a preliminary status of Critically Endangered (CR) is assigned. The new species deserves protection because its total area of occupancy is less than 100 km^2 (ca. 50 km^2) (B1); only three populations are known (B1b); habitat inferred to be continuing to decline (B1b(i-iii)); population estimated to number fewer than 300 individuals (D). The suitable habitats for *S. moqueguensis* on the mountain summits near the set of lakes in the Ubinas district are regarded as endangered because overgrazing of grasslands, changes in annual rainfall, volcanic activity, and exploitation of natural resources may all potentially reduce their extent.

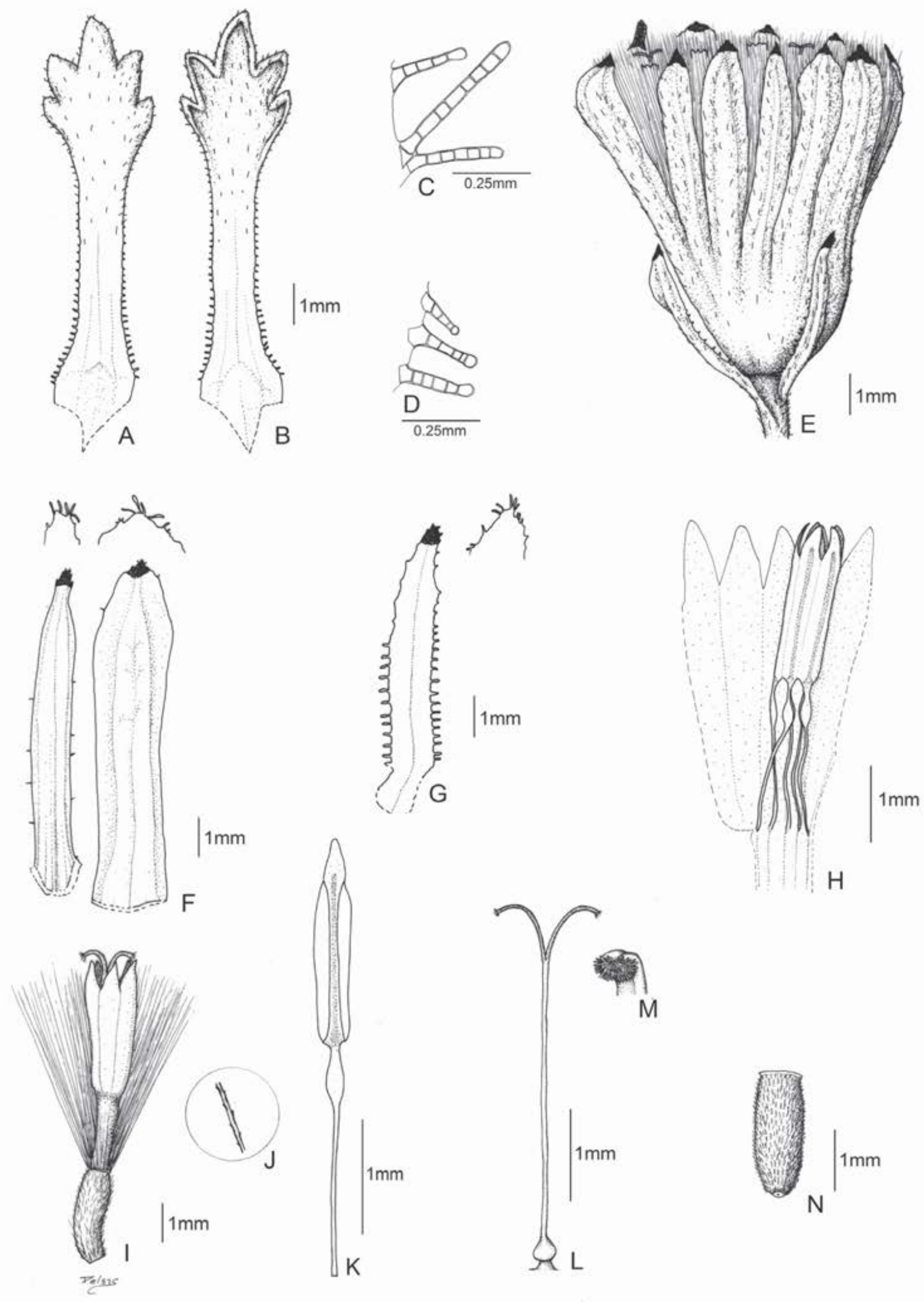


Figure 1. *Senecio moqueguensis* Montesinos. A. Leaf (upper side); B. Leaf (underside); C. Phyllary trichomes; D. Leaf trichomes; E. Capitulum; F. Calycular bracts; G. Phyllary; H. Stamens arrangement in a floret; I. Floret; J. Pappus bristles; K. Stamens; L. Style; M. Papillose stigma; N. Achene.

Senecio sykorae **Montesinos, sp. nov.**
urn:lsid:ipni.org:names:77140250-1
Figs 2, 4B, 5

Diagnosis: Morphologically similar to *Senecio gamolepis* but clearly distinguished by the tuft mat habit (vs. cushion mats), the leaf shape being obovate-spathulate (vs. linear-lanceolate), corolla white (vs. yellow), phyllaries 12–14 (vs. 7–9), disc length 7–9 mm (vs. 8–12 mm), and achene length 1.5–2 mm (vs. 1–1.3 mm).
Type: PERU: Moquegua Region, General Sánchez Cerro Province, Yunga District, E of Yunga, terrestrial on bare clayey soils on the peaks of Perusa mountain, elevation 4802 m, 16°11'08"S, 70°38'14"W, 13 April 2012, *Montesinos & Calisaya 3805* (holotype USM!, isotype HUSA!).
Description: *Perennial* herb, decumbent, low-growing and forming small tuft mats 4–6 cm high and up to 6 cm in diam. *Trichomes* absent. *Stems* 3–5 cm long, densely leafy, woody and branched at the base. *Leaves* cauline, alternate, lamina obovate-spathulate, 9–14 mm long × 1–2.2 mm wide, glabrous on surface and margins except at the base (scarcely covered by thin, short trichomes), base truncate to auriculate, apex obtuse, entire, margin involute; young leaves pale green with yellowish margins turning dark green with age. *Synflorescences* of solitary, terminal capitula. *Capitula* homogamous, discoid and pedicled (5–10 mm long). *Involucres* at first narrowly cylindrical becoming cylindrical-campanulate with age (7–9 mm long × 3–5 mm wide). *Calycular bracts* linear-oblong (6–8 mm × 0.7–1 mm), dark green on the surface and light green along the margins, with dark brown-black apex covered with inconspicuous trichomes or glabrous. *Phyllaries* 12–14, connate, 5–6.5 mm long × 0.6–1 mm wide, linear-lanceolate, margins glabrous, apex dark brown with short trichomes. *Florets* 13–16; corolla tubular, abruptly constricted near the base, 5-lobed, each lobe 0.2–0.3 mm long, white, tube 2.5–4 mm long × 0.5–0.8 mm wide; anthers linear-lanceolate, 1.5–2 mm long × 0.2–0.3 mm wide, truncate, terminal appendages lanceolate, obtuse; margin whitish transparent and becoming darker towards the centre; style dark purple, truncate, apically covered by papillae equally distributed. *Achenes* cylindrical, pale green, finely covered with trichomes, 1.5–2 mm long × 0.6–0.9 mm wide; carpopodium symmetrical in a shallow ring; pappus of smooth fine bristles, white, 4–6 mm long, with fine alternate single setulae.
Ecology and distribution: Terrestrial plant on bare clayey soils on the summits of mountain peaks and grassland plateaus in the north of the Moquegua Region at elevations of 4550–4800 m. Co-occurring with *Belloa pickeringii* (A. Gray) Sagást. & M.O. Dillon, *Nototriche obcuneata* (Baker f.) A.W. Hill, *Pycnophyllum molle* Remy, *Senecio candollei* Wedd. and *Xenophyllum ciliolatum* (A. Gray) V.A. Funk. Flowers and fruits between March and April.

Etymology: This *Senecio* is named after Karlè Sýkora, a well-known Dutch vegetation scientist who was my mentor in phytosociology.

Additional material examined (paratypes): PERU. Moquegua Region, General Sánchez Cerro Province, Ubinas District, S of Pillone, terrestrial on bare clayey soils in the verges of the road to Pillone town, elevation 4584 m, 16°10'02"S, 70°49'56"W, 24 March 2013, *Montesinos 4023* (USM).

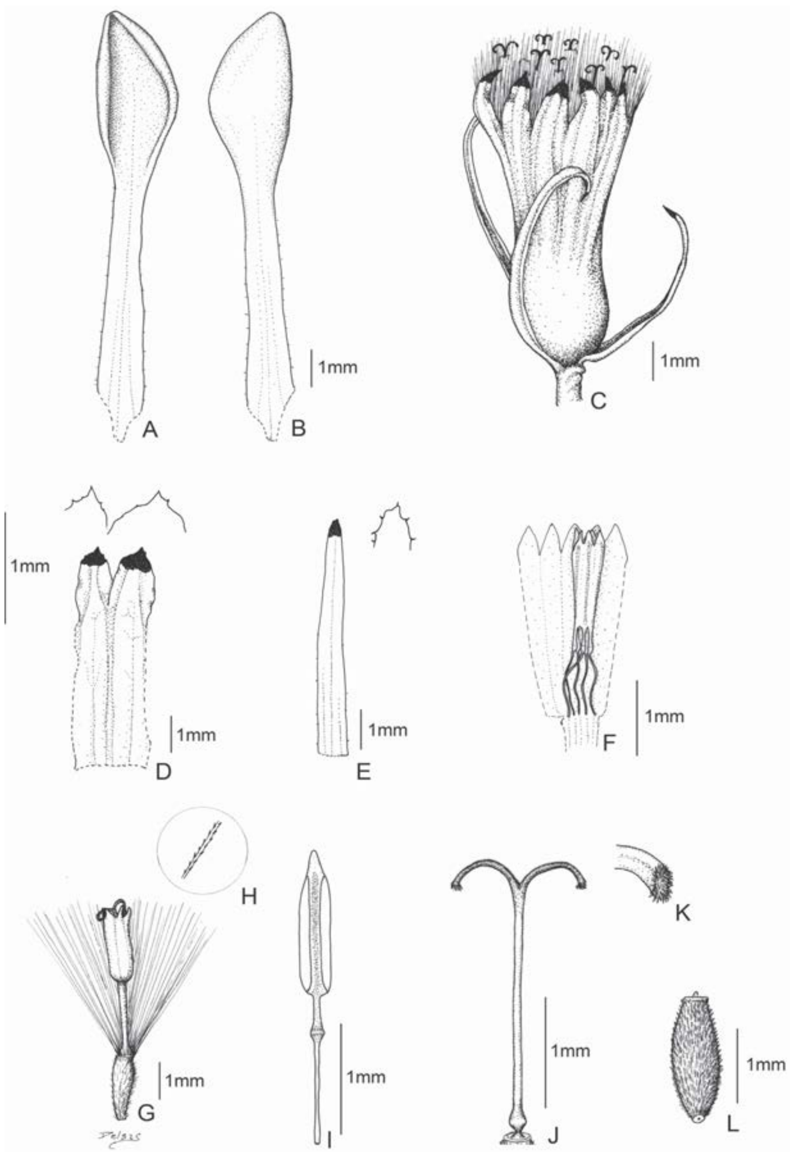


Figure 2. *Senecio sykorae* Montesinos. A. Leaf (upper side); B. Leaf (underside); C. Capitulum; D. Calycular bracts; E. Phyllary; F. Stamens arrangement in a floret; G. Floret; H. Pappus bristles; I. Stamens; J. Style; K. Papillose stigma; L. Achene.

Table 1. Comparison between *Senecio moqueguensis*, *S. sykorae*, *S. tassaensis* and their closest relatives.

	S. moqueguensis	*S. sykorae*	*S. tassaensis*	*S. pucapampaensis*	*S. gamolepis*
Distribution	Moquegua (PE)	Moquegua (PE)	Moquegua (PE)	Junín (PE)	PE, CH, AR, BO
Altitude	4500–4800 m	4550–4800 m	4650–4700 m	4500–4600 m	4000–4800 m
Habit	dense caespitose mat	tuft mat	tuft	postrate, decumbent	dense caespitose mat
Plant dimensions (height, diameter)	2–4 cm, > 60 cm	4–6 cm, > 6 cm	2–4 cm, > 4 cm	5–9 cm, > 8 cm	2–3 cm, > 1m
Indumentum	trichomes glandular, multicelular, 0.1–0.3 mm	absent	trichomes glandular, multicelular, 0.3–12 mm	finely puberulous, <0.1 mm	absent
Leaf shape	oblong-spathulate; subpinnatifid	obovate-spathulate	obovate-spathulate; incised or acuminate	cuneiform-subpinnatifid, incised	linear-lanceolate
Leaf (length, width)	8–12 × 1–2.5 mm	9–14 × 1–2.2 mm	6–9 × 1–2.5 mm	9–15 × 3–4 mm	8–12 × 2–4 mm
Leaf pubescence	sparsely covered by thin trichomes	glabrous	densely covered by trichomes	ciliate margins	glabrous
Involucre (shape, length, width)	cylindrical-campanulate; 7–10 × 6–8.5 mm	cylindrical-campanulate; 7–9 × 3–5 mm	cylindrical-campanulate; 6–8 × 5–7 mm	campanulate; 7–8 × 8–9 mm	cylindrical-campanulate; 8–11 × 4–6 mm
Calycular bracts (shape, margin, size)	linear-oblong; sparse trichomes; 6–9 × 1–2.5 mm	linear-oblong; scarce trichomes; 6–8 × 0.7–1 mm	ovate-oblong; dense trichomes; 4–6 × 1 mm	linear; ciliate; 6–7 × 1 mm	linear; glabrous; 7–10 × 0.8–12 mm
Phyllaries (shape, size)	oblong-lanceolate; 5–8 × 0.7–12 mm	linear-lanceolate; 5–6.5 × 0.6–1 mm	linear-lanceolate; 5–8 × 0.8–12 mm	linear; 6–7 × 12 mm	oblong; 6–8 × 18–2.3 mm
Phyllaries (number)	9–12	12–14	12–16	12–14	7–9
Phyllaries (margins)	densely covered with trichomes	glabrous	densely covered with trichomes	scarious, ciliate	glabrous
Corolla (color)	bright yellow	white	purple-pink to pale white	white	yellow
Achene (shape, texture)	cylindrical, with trichomes	cylindrical, with trichomes	ovate, striate, with trichomes	cylindrical, glabrous	cylindrical, glabrous
Pappus (length)	5–6 mm	4–6 mm	3.5–5 mm	5–6 mm	6–9 mm

	S. algens	*S. evacoides*	*S. humillimus*	*S. expansus*	*S. trifurcifolius*	*S. repens*
Distribution	PE, BO, AR	PE, BO, AR	BO, South Peru	AR, BO, PE	PE, BO, CH	BO, EC, PE
Altitude	4500–5000 m	4000–4800 m	3500–4500 m	3900–4800 m	4000–4500 m	3000–4600 m
Habit	cespitose subshrub	suffruticose or shrubby	dense caespitose mat	ground rosette herb	suffruticose	ground rosette herb
Plant dimensions (height, diameter)	4–6 cm, > 6 cm	2 cm, ca. 1m	2 cm, ca. 70 cm	2–4 cm, 5–8 cm	5–8 cm, > 8 cm	2–4 cm, 6–9 cm
Indumentum	absent	white lanuginose, < 0.2 mm	puberulous, 0.1–0.2 mm	densely lanuginose, < 0.2 mm	absent	puberulous, < 0.2 mm
Leaf shape	spathulate, obtuse	obovate-spathulate	linear-spathulate, ovate	ovate, elliptical or circular; crenate	cuneiform-linear, dentate	elliptic-ovate, obovate
Leaf (length, width)	10–35 × 2–5 mm	10–20 × 3–6 mm	3–10 × 0.5–1 mm	10–25 × 10–22 mm	10–20 × 1 mm	10–25 × 10–22 mm
Leaf pubescence	glabrous	densely lanuginose	sparsely puberulous	densely lanuginose	glabrous	glabrous adaxially, puberulous abaxially
Involucre (shape, length, width)	cylindrical-campanulate; 7.5–10 × 8–12 mm	campanulate; 7–8 × 5–6 mm	cylindrical-campanulate; 5 × 3–4 mm	campanulate; 10–25 × 10–22 mm	campanulate; 8–9 × 6 mm	campanulate; 6–7 × 8–10 mm
Calycular bracts (shape, margin, size)	linear; glabrous; 6–9 × 0.8–11 mm	linear; tomentose; 6–7 × 0.8–12 mm	linear; glabrous; 3–4 × 0.7–1 mm	linear; tomentose; 9–22 × 2.5–5 mm	linear, glabrous; 7–8 × 0.8–12 mm	linear, glabrous; 5–6 × 0.8–12 mm
Phyllaries (shape, size)	linear; 7–9 × 2–3 mm	linear; 5–7 × 0.8–11 mm	oblong-lanceolate, 6–8 × 1–12 mm	linear; 10–15 × 2–4 mm	lanceolate, attenuate; 6–8 × 1–15 mm	linear; 13–20 mm × 1–2 mm
Phyllaries (number)	10–15	13–20	8	20–25	8	13–20
Phyllaries (margins)	glabrous	pubescent	glabrous	glabrous or pubescent	glabrous	glabrous
Corolla (color)	yellow	yellow	dark yellow with purple tube	yellow	yellow	yellow
Achene (shape, texture)	cylindrical, glabrous	cylindrical, glabrous	cylindrical, sericeous	cylindrical, glabrous	cylindrical-ovate, densely sericeous	cylindrical, glabrous
Pappus (length)	6–8 mm	4–6 mm	5–7 mm	10–20 mm	6–7 mm	5–6 mm

Discussion: *Senecio sykorae* appears to be closely related to *S. gamolepis* which grows at higher elevations but approaches the known range of *S. sykorae* within a few hundred metres. While *S. gamolepis* is generally distinctive in the genus for its large size, attaining widths of up to 1 meter in diameter, and for its larger, capitulate form, *S. sykorae* is a smaller plant, of about 4–6 cm wide and has shorter corolla, less than 9 mm long. *Senecio sykorae* is also distinctive in that it has 12–14 phyllaries per capitulum instead of 7–9 phyllaries in *S. gamolepis*. Likely the leaves of *S. sykorae* are distinctive in that they are obovate-spathulate vs. linear-lanceolate. Also, the achenes in *S. sykorae* are larger (1.5–2 mm long) vs. 1–1.3 mm long in *S. gamolepis. Senecio sykorae* also differs from *S. algens* by the leaf and capitula length (shorter in *S. sykorae*), and from both species by the corolla colour (white vs. yellow). Less similarity is found in *S. algens*, *S. humillimus*, *S. trifurcifolius*, *S. pucapampaensis* and *S. evacoides*, and from which *S. sykorae* can be distinguished on the basis of its habit, trichomes, leaf shape and length, calycular bracts and phyllary length and shape as summarized in Table 1.
Conservation status: Following the criteria and categories of IUCN (2001), a preliminary status of Critically Endangered (CR) is assigned. The new species deserves protection because its total area of occupancy is less than 10 km² (ca. 5 km²) (B2); only one population known (B2b); habitat inferred to be continuing to decline (B2b(i-iii)); population estimated to number fewer than 150 individuals (D). The suitable habitats for *S. sykorae* on the mountain summits of the north of Moquegua are indicated as endangered because of overgrazing of grasslands, changes in annual rainfall, volcanic activity, and exploitation of natural resources, all potentially reducing their extent.

***Senecio tassaensis* Montesinos, sp. nov.**
urn:lsid:ipni.org:names:77140251-1
Figs 3, 4C, 5

Diagnosis: Similar to *Senecio moqueguensis* but clearly distinguished by the leaf lamina obovate-spathulate (vs. oblong-spathulate), leaf length 6–9 mm (vs. 8–12 mm), leaf surface densely covered by trichomes (vs. sparsely covered), trichomes 0.3–1.2 mm long (vs. 0.1–0.3 mm long), corolla white (vs. yellow), calycular bracts 4–6 mm long (vs. 6–9 mm), phyllaries 12–16 (vs. 9–12), involucre length 6–8 mm (vs. 7–10 mm), and achene length 1–1.2 mm (vs. 1.8–2.5 mm).
Type: PERU. Moquegua Region, General Sánchez Cerro Province, Ubinas District, NW of Tassa, terrestrial on clayey rocky soils on the summits of Pirhuani peak, elevation 4657 m, 16°09'58"S, 70°43'49"W, 07 April 2011, *Montesinos 3103* (holotype HUSA!, isotypes MOL, USM).
Description: *Perennial* herb, tufted, up to 2–4 cm high and up to 4 cm in diam. *Trichomes* glandular, densely covering the plant, multicellular, whitish transparent, 0.3–1.2 mm long × 0.1–0.2 mm wide, composed of 6–10 ovate or elongate cells (each 60–80

μm long), apical cell rotund. *Stems* thick, < 1 cm long, often densely branched and leafy in the central portion. *Leaves* arranged in irregular rosettes, lamina obovate-spathulate, 6–9 mm × 1–2.5 mm, densely covered by thin trichomes on the margins; base truncated and apex pinnatifid; lower and upper surface of the leaves gradually becoming shorter towards the tip; margin incised with 5–7 obtuse lobes or rarely acuminate; mature leaves with involute margins; young leaves green yellow turning greenish grey with age. *Synflorescences* of solitary sessile or subsessile terminal capitula. *Capitula* homogamous, discoid. *Involucres* at first cylindrical, turning campanulate with age (ca. 6–8 mm long × 5–7 mm wide). *Calycular bracts* ovate-oblong (4–6 mm × 1 mm), greyish green on the surface and covered with trichomes on the margins, dark brown apex covered apically with short brown multicellular trichomes. *Phyllaries* 12–16, connate, 5–8 mm long × 0.8–1.2 mm wide, linear-lanceolate, covered with thin trichomes scarcely on the surface and densely along the margins, apex dark brown and covered with short multicellular trichomes. *Florets* 18–21, corolla tubular, abruptly constricted near the base, 5-lobed, each lobe 0.2–0.4 mm long, purple pink gradually becoming pale white towards the tip, tube 2–2.5 mm long × 1 mm wide; anthers linear-lanceolate, 1.5–2 × 0.3–0.4 mm, terminal appendages lanceolate, acute to somewhat protuberant, bases ecalcarate; anthers margin white becoming dark yellow towards the centre; style dark purple, truncate, papillae covering the whole surface of the apex. *Achenes* ovate, striate, covered with trichomes, 1–1.2 mm long and 0.6–0.8 mm wide, pale yellow; carpopodium symmetrical in a shallow ring; pappus of smooth bristles, white, silky, 3.5–5 mm long, with fine single setulae.

Ecology and distribution. Terrestrial plant on clayey rocky soils on the peaks of the highland summits of the Pirhuani peak, near Tassa town, Moquegua Region, at elevations of 4650–4700 m. It occurs with *Azorella*, *Calamagrostis*, *Pycnophyllum*, *Mniodes*, *Senecio*, and *Xenophyllum*. Flowers and fruits between March and April.

Etymology. This *Senecio* is named after the town of Tassa (Moquegua Region), downslope of Pirhuani peak where the species was found.

Discussion. *Senecio tassaensis* appears to be closely related to *S. moqueguensis* which grows at the same elevational range but approaches the known range of *S. tassaensis* within a few hundred metres. *Senecio moqueguensis* is generally distinctive in the series for its larger size, attaining dense ground mats, and for its yellow corolla. *Senecio tassaensis* has 12–16 phyllaries (vs. 9–12), an involucre length of 6–8 mm and achene length of 1–1.2 mm, being much shorter than in *S. moqueguensis*. *Senecio tassaensis* is relatively a very rare species with an estimated 100 individuals known. It is less similar to *S. pucapampaensis*, *S. evacoides*, *S. expansus* and *S. repens*, and can be distinguished on the basis of the habit, trichomes, leaf shape and length, calycular bracts and phyllaries length and shape as summarized in Table 1.

Conservation status. Following the criteria and categories of IUCN (2001), a preliminary status of Critically Endangered (CR) is assigned. The new species deserves protection because its total area of occupancy is less than 10 km² (ca. 5 km²) (B2); only one population is known (B2b); habitat inferred to be continuing to decline (B2b(i-iii)); population estimated to number fewer than 100 individuals (D). The suitable habitats for *S. tassaensis* on the mountain summits of Pirhuani peak in the Ubinas district are indicated as endangered, because changes in the annual rainfall, volcanic activity and exploitation of natural resources, may all reduce their extent.

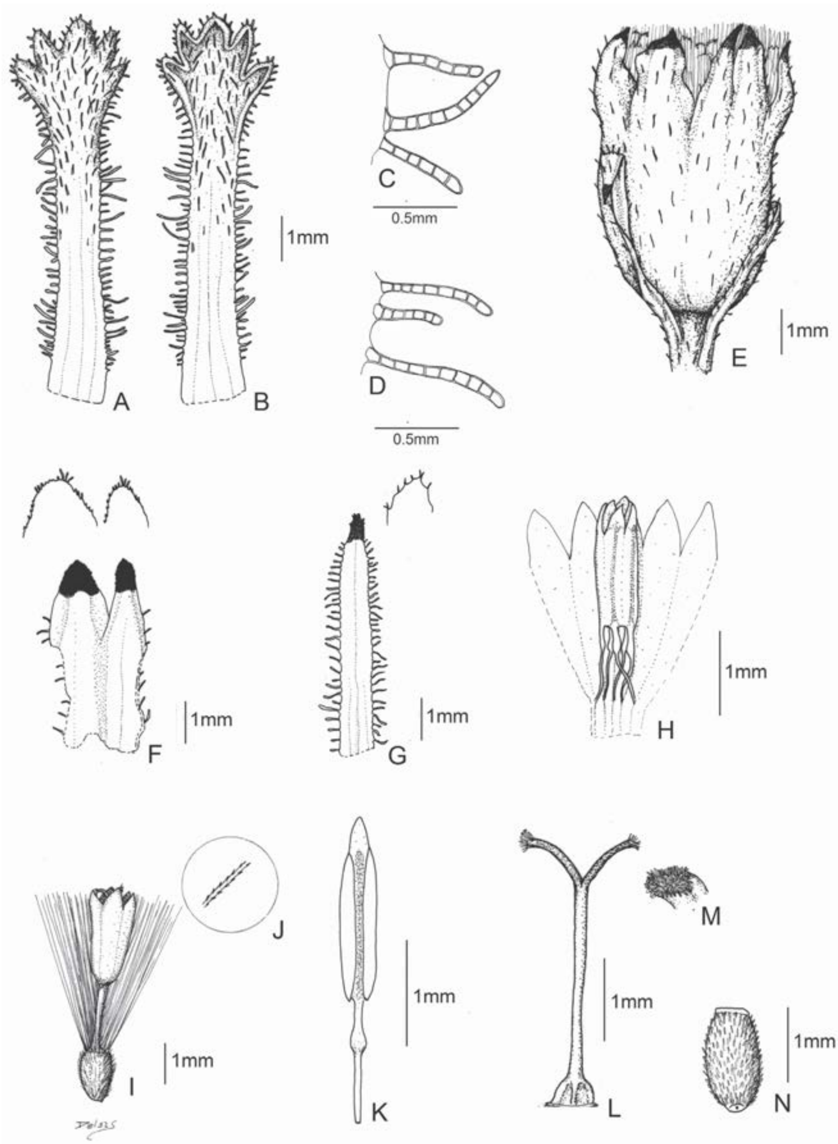


Figure 3. *Senecio tassaensis* Montesinos. A. Leaf (upper side); B. Leaf (underside); C. Phyllaries trichomes; D. Leaf trichomes; E. Capitulum; F. Calycular bracts; G. Phyllary; H. Stamens arrangementn a floret; I. Floret; J. Pappus bristles; K. Stamens; L. Style; M. Papillose stigma; N. Achene.

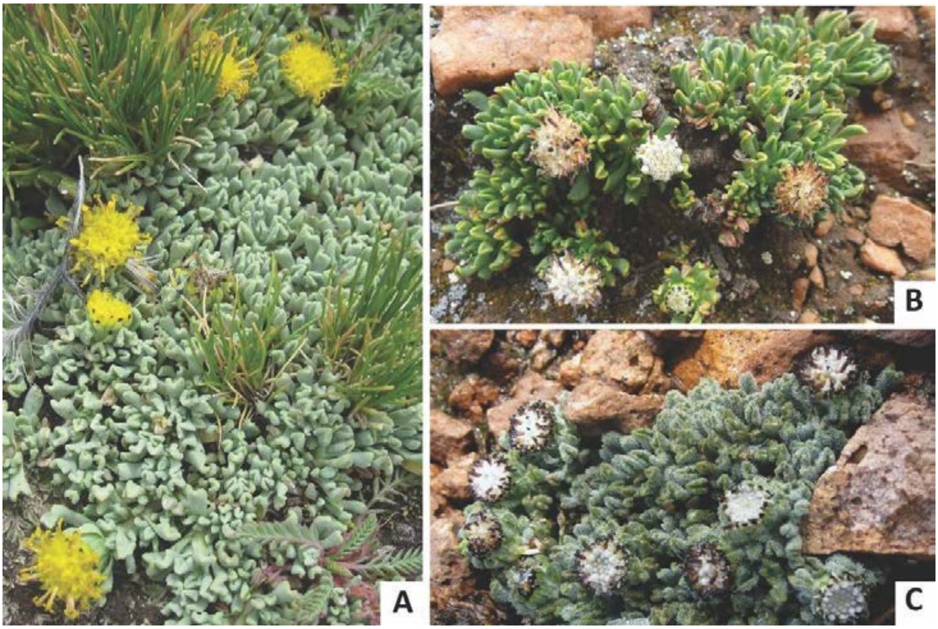


Figure 4. Habit photographs of: A. *Senecio moqueguensis*; B. *Senecio sykorae*; C. *Senecio tassaensis*.

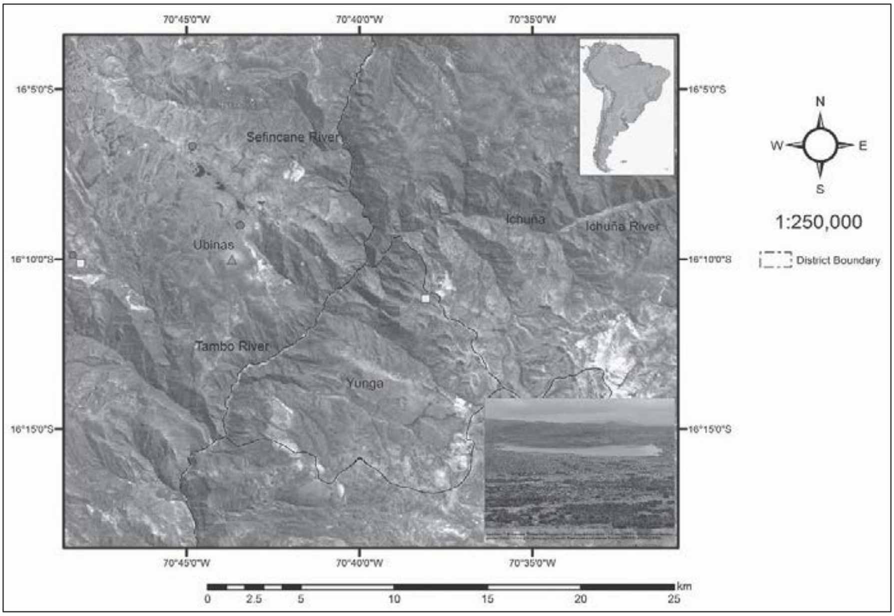


Figure 5. Distribution map showing collection and recorded sites for *Senecio moqueguensis* (red circles), *S. sykorae* (yellow squares) and *S. tassaensis* (green triangles). Inset: Photograph of the highland plains of Tassa, Moquegua, where populations of *S. moqueguensis* occur.

Key to the species of *Senecio* ser. *Suffruticosi* subser. Caespitosi in Peru (adapted from Cabrera 1985, Cabrera et al. 1999)

1a Plants shrubby; involucres longer than 11 mm **2**
1b Plants caespitose; involucres shorter than 11 mm long........ **5**
2a Achenes densely pubescent; leaves 1–2 cm long, deeply dentate or lobulate .... ***S. adenophyllus***
2b Achenes glabrous; leaves 1–3.5 cm long, entire **3**
3a Leaves 3–5 mm wide; involucre bracts oblong .... ***S. rufescens***
3b Leaves 0.7–2 mm wide; involucre bracts linear **4**
4a Leaves 25–80 mm long; phyllaries 13–18 .... ***S. scorzonerifolius***
4b Leaves 15–25 mm long; phyllaries 15–20 .... ***S. danai***
5a Capitulum small; involucre shorter than 5 mm........ **6**
5b Capitulum larger; involucre shorter than 11 mm **7**
6a Leaves entire, glabrous and fleshy; phyllaries 8 .... ***S. humillimus***
6b Leaves entire or dentate, glabrous or lanuginose; phyllaries 13 .... ***S. vegetus***
7a Plants tomentose, at least on the underside of leaves **8**
7b Plants glabrous........ **13**
8a Plants with dense pubescence covering all plant parts **9**
8b Plants with sparse pubescence not covering all plant parts........ **11**
9a Leaves spathulate, 10–20 mm long; involucre 7–8 mm tall; phyllaries 13–20........ ***S. evacoides***
9b Leaves ovate, elliptic or circular, crenate, 10–65 mm long; involucre 6–10 mm tall; phyllaries 13–25 .... **10**
10a Involucre 10–25 mm long; phyllaries 20–25 .... ***S. expansus***
10b Involucre 6–7 mm long; phyllaries 13–20 .... ***S. repens***
11a Leaves cuneiform, lamina glabrous except puberulous margins .... ***S. pucapampaensis***
11b Leaves oblong, lamina with trichomes on surfaces and margins **12**
12a Leaves 8–12 mm long, lamina oblong-spathulate; involucre 7–10 mm; phyllaries 9–12 .... ***S. moqueguensis***
12b Leaves 6–9 mm long, lamina obovate-spathulate; involucre 6–8 mm; phyllaries 12–16 .... ***S. tassaensis***
13a Leaves dentate, linear-cuneiform........ ***S. trifurcifolius***
13b Leaves entire **14**
14a Leaves 10–35 mm long .... ***S. algens***
14b Leaves less than 14 mm long........ **15**
15a Leaves 8–12 mm, linear-lanceolate; involucre 8–11 mm; phyllaries 6–8........ ***S. gamolepis***
15b Leaves 9–14 mm, obovate-spathulate; involucre 7–9 mm; phyllaries 12–14........ ***S. sykorae***

Arenaria acaulis (Caryophyllaceae), a new species from South Peru

Montesinos-Tubée, D.B. & Kool, A.
Phytotaxa (2015) 220(1): 77–82

Abstract

During studies on the flora of Moquegua (Southern Peru), some interesting *Arenaria* populations (subgen. *Dicranilla*, Caryo- phyllaceae) were found. The morphology of the plants does not resemble any other neotropical *Arenaria* species. The most similar species known so far is *Arenaria boliviana* (from Bolivia and Peru) from which it differs in having a shorter stem length, ciliate (not glabrous) short branches; ovate rather than oblong-lanceolate leaves always covered with dense, long trichomes, never glabrous; pedicels shorter than or equal to the size of the calyx (not twice as long), sepals broadly ovate (not ovate-oblong) and with glabrous surface, as well as in the petals. Hence, a new species-*A. acaulis*-is here described and illustrated.

Key words: Arenaria, new species, Peru, South America

Introduction

Arenaria Linnaeus (1753: 423) is a genus of about 200 species distributed in Eurasia, America, and northern Africa (Williams 1898, Zhou 1996, Hartman *et al.* 2005). The species of *Arenaria* are annual or perennial (often caespitose), with leaves ovate to lanceolate, petals usually with margins entire, stamens 10, disk more or less developed, (2–)3 styles and capsules opening with twice as many teeth as there are styles (Macbride 1937, McNeill 1962, Volponi 1985, Hartman 2005) Based on molecular data *Arenaria* was shown to be polyphyletic by Fior (2006, 2007) a result that was further corroborated by Harbaugh et al (2010) and by Greenberg et al (2011). Harbaugh *et al.* (2010) proposed to accommodate the members of *Arenaria* subgen. *Eremogone* (Fenzl 1833: 13) Fenzl (1842: 360) and subgen. *Eremogoneastrum* F.N. Williams (1895: 598) in *Eremogone* and to recognize *Arenaria* subgen. *Odontostemma* (Bentham ex G.Don 1831: 449) F.N. Williams (1895: 603) as a separate genus, The South American members of the genus (ca. 50 species) belong to subgen. *Dicranilla* (Fenzl 1840: 967) F.N.Williams (1895: 599) and subgen. *Leiosperma* McNeill (1962: 105). Several members of subgen. *Leiosperma* were shown to belong in *Arenaria* s.str. by Harbaugh *et al.* (2010), and by Greenberg *et al.* (2011), but no members of subgen. *Dicranilla* have been included in any phylogenetic study so far. A recent taxonomic review is lacking for both these South American subgenera, although several local taxonomic treatments and floras were published (Reiche 1860; McNeill 1962; Volponi 1985, 2012; Brako & Zarucchi 1993; Jørgensen & Ulloa Ulloa 1995; Zuloaga et al. 2008). In Peru, 21 species are currently known to occur (Macbride 1937; Brako & Zarucchi 1993), of which two are recorded in Moquegua region, South Peru (Montesinos-Tubée 2012a). The mountain highlands of Moquegua are an interesting geographical area not least because of the high level of endemism. The highland plateaus and superficial rocky slopes are particularly interesting, and they are usually inhabited by cushion plants and leptophyllous shrubs, which provide niches for a wide variety of otherwise rare rosette plants, and other flowering plants.

Materials and methods

Since 2009 the first author has examined over 800 specimens of *Arenaria* occurring in the Andes and housed in Peruvian herbaria (CUZ, HSP, HUT, HUSA, MOL, USM), from institutions abroad (B, BR, F, KEW, L, LPB, MO, P, WAG), and material from the first author's recent fieldwork. Digitised specimens were viewed via online herbarium catalogues of Tropicos (2014) and JSTOR (2014). Acronyms follow Thiers (2014+). All morphological characters were studied under a NSZ-405 1X-4.5X stereo microscope and an AmScope M100C- LED 40×-1000× compound microscope. Conservation assessments were undertaken using the IUCN Red List Criteria (IUCN 2014).

Results and Discussion

Arenaria acaulis Montesinos & Kool, *sp. nov.* (Figs. 1–2)
Type: PERU. Moquegua Region: General Sánchez Cerro Province, Ubinas District: Larsepesca site, terrestrial on clayey rocky soils on the plateau peaks between Coalaque and Tassa towns, 4653 m, 16°08'32"S, 70°43'08"W. 4 April 2009, *Montesinos 2475A* (holotype USM!, isotypes MO–2219338!, HUPCH–4221). Image of the isotype at MO available at http://tropicos.org/Specimen/100196348

Diagnosis: The new species is morphologically similar to *Arenaria boliviana* but is clearly distinguished by the shorter stem length, ciliate (not glabrous) short branches; ovate rather than oblong-lanceolate leaves always covered with dense, long trichomes, never glabrous; pedicels shorter than or equal to the size of the calyx (not twice as long), sepals broadly ovate (not ovate-oblong) and covered with trichomes as opposed to usually glabrous, as well as by the presence of petals.

Description: Perennial herb, deep rooted, pulvinate, forming solitary tufts 0.8–1.2 cm tall and 4–6 cm in diameter. *Stems* 5–10 mm long, often densely branched and covered by older leaves in the central and lower parts; internodes short, less than 0.2 mm in length. *Leaves* opposite, imbricate, gradually reduced in length and width upward on stem, the largest near the central portion and base; lamina ovate, 1.2–1.9 mm × 0.8–1.2 mm, densely covered by thin trichomes (about 0.1–0.4 mm long) on the margins except in the surfaces and the base; base truncated and apex acute; leaves light green with greenish round dots near the pale red midrib, margins also pale red. *Flowers* solitary, with short pedicels of about 0.2–0.5 mm long and covered with short, fine trichomes. *Calyx* cylindrical to narrowly campanulate, the 5 sepals mostly 0.8–1.2 mm long, ovate, apically obtuse or rounded, light green and inconspicuously 1-veined, with densely scarious margins. *Corolla* tubular in early anthesis, becoming narrowly campanulate, the petals shorter than the sepals, ca. 1.2 mm long, the blades broadly ovate, glabrous, apically rounded or obtuse, pale white-greenish, with an inconspicuous midrib. *Stamens* usually 10, spreading-ascending, the filaments linear (ca. 0.8–1.2 mm long), white, the anthers elliptical, pale-yellow and reniform (ca. 0.2 mm long). *Ovary* ovoid, ca. 0.7 mm long, pale yellow- white; styles 3, at anthesis 1–1.5 mm long, erect or slightly spreading, the curved, minute, scarious stigmas ca. 0.35 mm long. *Capsule* broadly ovoid, enclosed by the persisting calyx and petals, 1.7–2 mm long and somewhat incurved; *seeds* 10–16, rounded, 0.4–0.6 mm in length, rounded to some extent elliptic, surface reddish-brown, shiny, and rarely granulate.

Etymology: The epithet *acaulis* refers to the tufted and acaulescent habit of the species.

Ecology and distribution: *Arenaria acaulis* is distributed on highland plateaus of the Moquegua Region (South Peru). It grows on rocky slopes at an elevation of 4450–4700 m.a.s.l. Associated species are: *Astragalus peruvianus* Vogel (1843: 18), *Azorella compacta* Phil. (1891: 28), *Mniodes pulvinata* Cuatrec. (1954: 5), *Pycnophyllum molle* J.Remy (1846: 355), and the endemics: *Nototriche digitulifolia* A.W. Hill (1948: 127), *Senecio moqueguensis* Montesinos (2014: 3–6) and *Senecio sykorae* Montesinos (2014: 6–11). Flowering and fruiting between March and April.

Taxonomical notes: The new species is unique among the Neotropical *Arenaria* because of its dense cover of trichomes and the tufted, cushion-like habit. *A. acaulis* most closely resembles *A. boliviana* (Williams 1898: 425) MacBride (1936: 597–598). It differs by its shorter stem and internode length, the short branches being ciliate; the leaves ovate and densely covered by long trichomes; pedicels shorter or equal to the size of the calyx, sepals broadly ovate and densely covered with trichomes, and by the presence of petals.

The new species is further differentiated from *A. dicranoides* Kunth (1823: 34) by the habit, plant size, height and leaf shape, where in *A. acaulis* leaves are smaller and have a smooth tip, not coriaceous. *A. nitida* (Bartling 1831: 12) Rohrbach (1872: 249) differs in its leaves being larger and bisulcate and also by the glabrous sepals.

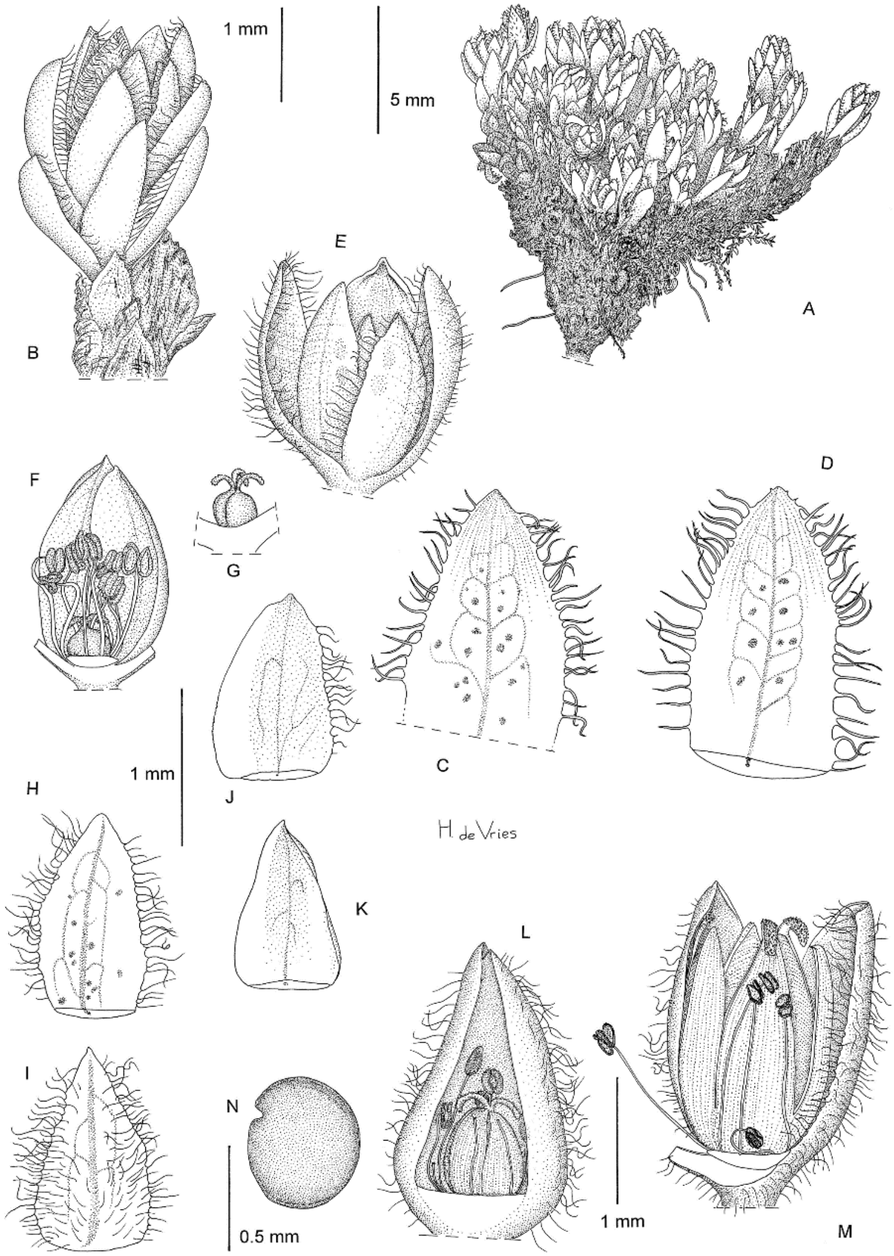


Figure 1. A. Habitus: complete plant (X 8); B. Branch with flower (X 30); C. Leaf, outside (X 50); D. Leaf, inside (X 50); E. Flower (X 50); F. Flower, opened (X 50); G. Ovary (X 50); H. Sepal, inside (X 50); I. Sepal, outside (X 50); J. Petal, inside (X 50); K. Petal (other), inside (X 50); L. Opened flower = very young fruit (X 40); M. Fruit, 1 sepal and 1 petal removed (X 40); N. Seed (X 65). Drawing by H. de Vries.

Figure 2. Habit of *Arenaria acaulis* (along road between Matazo and Querala, Ubinas district, at 4584 m).

Conservation status: On the basis of the IUCN criteria and categories (IUCN 2014), a status of Critically Endangered (CR) is assessed. The total area of occupancy (AOO) is less than 10 km² (ca. 5 km²) (criterion B2), only one population is known, despite extensive fieldwork in the area by the first author (B2a), habitat inferred to be continuing to decline [B2b(i–v)), population estimated to number fewer than 150 individuals (criterion D). The suitable habitats for *A. acaulis* on the mountain summits of the north of Moquegua are indicated as endangered because of overgrazing of grasslands, changes in annual rainfall, volcanic activity, and exploitation of natural resources, all potentially reducing their extent.

Additional material examined (paratypes): PERU. Moquegua Region, General Sánchez Cerro Province, Ubinas District, terrestrial on highland rocky slopes near Larsepesca, Coalaque town, 4677 m, 16°08′19″ S, 70°43′15″ W, 21 March 2009, *Montesinos 2475B* (USM, MO–2274701); Moquegua Region, General Sánchez Cerro Province, Ubinas District, terrestrial on clayey rocky soils on the Querala plateaus, 4618 m, 16°07′12″ S, 70°50′09″ W, 24 March 2013, *Montesinos 4026* (USM, HSP); Moquegua Region, General Sánchez Cerro Province, Ubinas District, terrestrial on rocky slopes close to the road between Matazo and Querala, 4584 m, 16°10′02″ S, 70°43′15″ W, 28 March 2015, *Montesinos 4241* (USM, HSP, HUT).

Tigridia arequipensis (Iridaceae: Tigridieae), A new species from South Peru

Montesinos-Tubée, Pauca, A & Revilla, I.
Blumea (2016) 61: 4–7.

Abstract

Tigridia arequipensis (Iridaceae: Tigridieae) is a new species found in the province of Arequipa (department of Arequipa), South Peru. It is unique by its white to pale white (or pale lilac) flowers, outer tepals with purplish-maroon and dark yellow spots and stripes, and inner tepals with pale purplish and bluish spots and stripes. *Tigridia arequipensis* is morphologically similar to *T. raimondii* Ravenna and *T. philippiana* I.M. Johnst., it differs by having longer basal leaves, narrower and larger bracts, and outer tepals ovate and longer fruits.

Keys words: Arequipa; Iridaceae; new species; South Peru; Tigridia

Introduction

Tigridia Juss. (Iridaceae: Tigridieae) is a New World genus of about 50 species (Rodriguez & Ortiz-Catedral 2003). In Peru there are 11 known species (Macbride 1936, Brako & Zarucchi 1993, Goldblatt 1998, Tropicos 2014). Six species are endemic to this country and the knowledge of their distribution is still incomplete (León 2006). The discontinuous geographic distribution in North and South America offers an ideal model to explore biogeographical aspects (Rodríguez & Ortiz-Catedral 2003). The variation in colour, size and form of the perianth in *Tigridia* indicate that the adaptation of the pollinators has been an important factor for its diversification (Rodríguez & Ortiz-Catedral 2003). Presumably the species of *Tigridia* are hummingbird-pollinated (Rudall et al. 2003); they secrete copius amounts of sugary nectar from nectaries on the inner tepal claws (Cruden 1971).

Celis (2012) studied the phylogenetic relations of the tribe Tigridieae suggesting new combinations in *Tigridia* and *Mastigostyla* based on plastid (cpDNA) and nuclear (nDNA) genomes.

During February and March of 2011 and 2012, we collected a tall *Tigridia* on the xeric scrublands of the province of Arequipa (department of Arequipa), South Peru. After a detailed morphological analysis, we conclude that this is an undescribed species.

Taxonomy

Tigridia arequipensis Montesinos, Pauca & I. Revilla, sp. nov. (Figs. 1)
Subgenus: *Tigridia*

Diagnosis: The new species is morphological similar to *Tigridia raimondii* and *T. philippiana* but is clearly distinguished by the white to pale white (or pale lilac) outer tepals with purplish–maroon and dark yellow spots and stripes, and inner tepals with pale purplish and bluish spots and stripes. Moreover it differs by having longer basal leaves and fruits, narrower and larger bracts and longer style branches.

Type: *Revilla 156* (holotype HSP! isotype MOL!). Peru. Arequipa Region, Arequipa Province, District of Quequeña, road to Sogay, terrestrial on clayey-sandy rocky soils on rocky slopes, elevation 2676 m, 16°33'31.77"S, 71°26'20.40"W, 29 March 2011.

Description: Erect bulbous perennial herb 60–90 cm high, glabrous, bulb ovoid to narrowly ovoid, 2.5–3 cm long, 1.2–2.5 cm wide, the outer tunics thin, pale to dark brown, densely clothed. Leaves: basal leaf linear, conduplicate, 29–62 cm long, 3–8 mm wide, equal or bigger than the flowering stems, cauline leaves 1–3, rarely 4, linear, plicate, the lower 28–62 cm long, 3–9 mm wide and the upper 12–30 cm long, 1.5–7 mm wide; flowering stem to 82 cm high. Inflorescence a rhipidium with the bracts subequal, 3–6.5 cm long and 4.5–6 mm wide, conduplicate, acute; pedicels 4–5.5 cm long, sulcate; inflorescence with 5–9 flowers by rhipidium, erect, 5–7 cm in diameter and 1–1.5 cm length, the tepals connivent at base forming a shallow cup, margin entire, spreading distally, basally brilliant brown. Tepals: Outer tepals, ovate, entire, acuminate, 1.9–2.3 cm long, 7–9 mm wide, white to pale white (or pale lilac) with purplish–maroon and dark yellow spots and stripes; inner tepals, ovate to deltoid, uniguiculate at the base, 1.9–2.2 cm long, 8–9 mm wide, white to pale white or pale lilac blue with pale purplish and bluish spots and stripes, glands disposed at the mid base of the inner tepals, semi-circular, brilliant. Filaments connate for ca. 1.2 cm, anthers oblong, ascendant, 4–5.5 mm long, 1–1.5 mm wide. Style branches (3) 3–4 mm long, deeply bifid into 2 style arms, pale yellow to pale purple. Capsules ellipsoid, 1–2.2 cm long, 3–5 mm wide, grooved and dark to pale brown. Seeds dark brown, shiny, 2 mm long and 1 mm wide.

Ecology and distribution: *Tigridia arequipensis* is distributed on clayey-sandy soils on rocky slopes, in the Arequipa Region in South Peru. It grows terrestrial on superficial soils on rocky slopes and occasional humid environs in xerophytic-scrubland communities at an elevation of 2490–3135 m and in association with *Ambrosia artemisioides* Willd., *Weberbauerocereus weberbaueri* (K. Schum. ex Vaupel) Backeb. *Solanum paposanum* Phil. *Anthericum eccremorrhizum* Ruiz & Pav. and *Mentzelia scabra* subsp. *chilensis* (Gay) Weigend. Flowering and fruiting between February and March, rarely on April. The distribution of the species is shown in a map (Figure 2) including *Tigridia albicans* Ravenna, *T. grandiflora* Salisb., *T. huyanae* (J.F. Macbr.) Ravenna, *T. lobata* (Herb.) J.F. Macbri., *T. minuta* Ravenna, *T. pavonia* (L. f.) DC., *T. pearcei* (Baker) Ravenna, *T. philippiana* I.M. Johnst., *T. purruchucana* (Herb.) Ravenna, *T. raimondii* Ravenna and *T. violacea* Schiede ex Chltdl. found in Peru (Ravenna 1964, 1969, 1988; Brako & Zarucchi 1993; Goldblatt 1998; León 2006; Tropicos 2014).

Etymology: *Tigridia arequipensis* is named after the province of Arequipa, where the species was found.

Additional material examined (paratypes): *Montesinos 3404* (CUZ, USM), Peru, District of Socabaya, Cerro Llorón, terrestrial on clayey-sandy rocky soils on rocky slopes, elevation 2490 m, 16°29’13”S, 71°32’31”W, 8 March 2012. *Montesinos 3495* (HSP, HUSA), Peru, District of Mollebaya, Molinoyoc, terrestrial on clayey-sandy rocky soils on rocky slopes, elevation 2820 m, 16°30’10”S, 71°26’44”W, 10 March 2012. *Revilla 170* (HSP, MOL), Peru, District of Quequeña, near Sogay, terrestrial on clayey-sandy rocky soils on rocky slopes, elevation 2749 m, 16°34’8.87”S, 71°24’33.47”W, 03 April 2011. *Revilla 188* (HSP, MOL), Peru, District of Alto Selva Alegre, Parque Ecológico, plain terrain with Cactaceae and shrub plants, terrestrial on clayey-sandy soils, elevation 3135 m, 16°19’31.89”S, 71°29’1.39”W, 10 April 2011.

Discussion

This species is known only from the xeric scrublands in the vicinity of the Arequipa city at elevations from 2490 to 3135 meters. The flowering stem begins to grow with the onset of the rainy season, and anthesis occurs shortly thereafter. Within *Tigridia arequipensis* two distinct morphological forms are recognizable. In the vicinity of Quequeña and Alto Selva Alegre the colour of the corolla is pale lilac to pale white with a reticulum of purple spots and stripes on both blade and limb of the outer tepals. Near Yarabamba and Socabaya, the plants have the colour of the corolla white to pale white, outer tepal purplish-maroon with dark yellow spots and stripes. *Tigridia arequipensis* is more similar to *T. raimondii* Ravenna and *T. philippiana* I.M. Johnst., in subgenus *Tigridia* (Molseed 1970), but it differs morphologically from the latter two species in having pale whitish flowers, the outer tepals ovate with purplish-maroon and dark yellow spots and stripes, and the inner tepals with with pale purplish and bluish spots and stripes. Furthermore, it differs by having longer basal leaves and fruits, narrower and larger bracts and longer style branches. Although *T. arequipensis* is a plant from high elevations, *T raimondii* and *T philippiana* grow at lower elevations and in drier habitats. The white-flowered *T. raimondii* is a plant of subhumid lomas in Atiquipa, Arequipa at elevations of 500–1500 meters, *T. philippiana* occurs in coastal areas of Antofagasta, Chile (Johnson 1929, Marticorena et al. 1998, Rodríguez & Marticorena 2000, Rosas 2010) and Ancash, Peru (Tropicos 2014). The new species is further differentiated from *T. albicans* Ravenna by the larger plant size, flower colour (yellow in *T. albicans*) and by the longer style. We compare the main characters of the new species and *Tigridia raimondii, T. philippiana* and *T. albicans* in Table 1.

Conservation status

Following the criteria and categories of IUCN (2012), a preliminary status of Vulnerable (VU) is assigned (A1a+D1). The new species deserves protection because its total area of occupancy is less than 200 km^2; population size estimated to number fewer than 200 individuals (D1); reduction in population size based on a direct observation of the reduction of the population mainly caused by human urbanization and habitat destruction (A1a). The suitable habitats for *T. arequipensis* on the xeric scrubland slopes in the Socabaya, Polobaya, Mollebaya and Quequeña districts are regarded as vulnerable because changes in annual rainfall, volcanic activity, exploitation of natural resources and uncontrolled urbanization, may all potentially reduce their extent.

Figure 1. *Tigridia arequipensis* Montesinos, Pauca & Revilla. A. Young plant in occasional humid soils near the waterfalls of Sogay, Quequeña district at 2914 m. B. Mature plant in a xeric-scrubland habitat, Cerro Llorón, Socabaya district at 2490 m. C. Xeric-scrubland habitat in Quequeña district at 2700 m. D. Flower opening at Misti volcano lower slopes, Alto Selva Alegre District, 2800 m. E. Flower and fruits at Sogay, Quequeña district at 2914 m. F. Mature flower in Cerro Llorón, Socabaya district at 2490 m. A, B, F and E photos by D.B.M.T., C and D by I. Revilla.

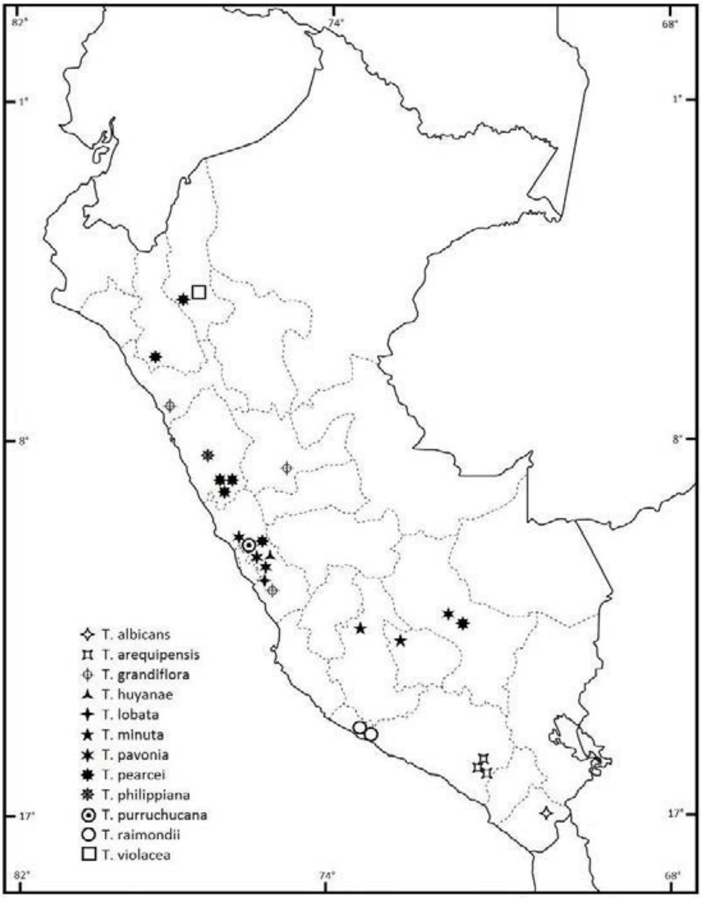


Figure 2. Map showing the distribution of ***Tigridia arequipensis*** and the other species occurring in Peru.

Table 1. Comparative data of some characters of *Tigridia arequipensis* and its closest relatives.

Species	Height (cm)	Number of cauline leaves	Leaf size (basal and cauline)	Style size (mm)	Flower colour	Tepal apex	Outer tepal	Inner tepal	Capsule shape (mm)	Distribution
T. raimondii	30–40	1	15–30 cm long, 14–18 mm wide		white with basal sect. purple	lobed	white	white-purplish	–	Atiquipa (Arequipa)
T. philippiana	25–45	1	15–40 mm long, 3–8 mm wide	2–2.5	white, pale yellow to pale purple	lobed	white-yellowish	white-yellowish	oblong, 2.8 by 7	N Chile, Ancash (Peru)
T. albicans	40	2	20 cm long, 5 mm wide	0.6	white	entire	white	white	circular, 8 by 5	Tacna
T. arequipensis	60–90	1–3	12–70 cm long, 1.5–9 mm wide	3–4	white to pale white (or pale lilac)	entire, acuminate	white to pale white (or pale lilac) with purplish maroon and dark yellow spots and stripes	white to pale white or pale lilac blue with pale purplish and bluish spots and stripes	ellipsoid 10–22 by 3–5	Arequipa province

CHAPTER 8

General Discussion

The Peruvian Andes

From north to south, the South American Andes mountain chain is 9000 km long (Salaverry Llosa 2006). The tropical Andes belong to the world's biodiversity hotspots (Myers et al. 2000). The altitude, topography and geology in the Andes are very diverse, which results in a complex biogeography. A large diversity of plant communities can be found in the southern Peruvian Andes, in dry valleys, highland mountain valleys, grassland plateaus, high altitude cushion bogs, lakes and on subnival summits.

Plant diversity in Peru is high. It is estimated that the country contains approximately 15.000 to 25.000 species of vascular plants, with about 5520 endemics (Brako & Zarucchi 1993; León et al. 2006; Convention on Biological Diversity 2014). Part of that floristic richness is attributable to Peru´s size (1.285.215,60 km2, extending from subequatorial to tropical latitudes ca. 18° South). Moreover, Peru is extremely varied in physiography, with altitudes ranging from sea level at the Pacific coast up to 7000 m in the Andes. The size and relief of Peru make it one of the most biogeographically diverse countries of South America.

Puna

The highlands of North Moquegua are characterized by a mosaic of puna formations. Puna is the name given to extensive highlands in the central and southern tropical Andes of South America and particularly to their distinctive alpine grassland vegetation (Cabrera 1968; Navarro 1993; Galán de Mera et al. 2003, 2009, 2011b, 2014; García & Beck 2006; Montesinos et al. 2012). The dry puna is one of the largest pastoral ecosystems, with a unique assemblage of shrubs, tussock grasses, cushion and mat-forming species (Smith 1994). The majority of the Peruvian puna grasslands are grazed by livestock, predominantly llamas and alpacas (Wilcox et al. 1986).

The puna can be subdivided as follows:
1. Prepuna (at altitudes between 3400 and 3800 m), comprising scrublands, spiny scrubs, xerophytic formations with dense scrublands, sandy river banks with cyclic succession, active and abandoned agricultural terraces, rocky slopes, humid grasslands, halophytic communities, caves with water seeping out of the rocks and afforestation stands of introduced trees);
2. Puna (at altitudes between 3800 and 4500 m), comprising scrublands, grasslands, *Puya raimondii* patches with tussocks and shrubs, rocky slopes, ravines, agricultural terraces, abandoned farmland, tree patches with *Escallonia myrtilloides*, humid grasslands, caves with water seeping out of the rocks and metamorphic formations. The importance of the conservation of the spectacular, endemic and endangered giant bromeliad *Puya raimondii* is widely recognized (Lambe 2009). *Puya raimondii*, a species with 2 to 3.5

(4) m tall stem rosettes with spiny, coriaceous leaves and with huge inflorescences can attain a height of 9–10 m.
3. Superpuna (at altitudes between 4500 and 4800 m), comprising rocky slopes, plateaus with grasslands and cushion plants, screes with copper-containing rock, manure communities, cryoturbation, cushion bogs and caves with water seeping out of the rocks (Montesinos et al. 2012; Montesinos-Tubée et al. 2015b). Cushion plants are abundant in the superpuna and several species are known to enhance diversity by nursing other species. In the north of Moquegua (South Peru), the superpuna vegetation is characterized by dwarf and erect shrubs, tussock grasses, annual herbs, ground rosettes, cushions, mats and annual grasses.

Although relatively species-poor, the vegetation of alpine rock communities is of great interest as it is adapted to harsh and extreme environments (Nowak et al. 2014a, 2014b) in which many endemics can be found. On steep rocky slopes many species growing in crevices (chasmophytes) can be found.

Anthropogenic pressure

As in other parts of South America, the Andes of South Peru are undergoing rapid population growth, which is accompanied by more livestock and thus overgrazing. The fragile ecosystems of the South Peruvian Andes are vulnerable to the population increase and the expansion of anthropogenic environmental degradation; the lack of environmental awareness, the mining activities and climate change are directly or indirectly leading to biodiversity change and to the migration of species. Fortunately, many sites still appear to be undisturbed.

Aims and objectives

The vegetation of the mountains of North Moquegua, located in the Andes of southern Peru, has been insufficiently studied and syntaxonomic knowledge is still incomplete. In this study many new syntaxa are described and revisions of published syntaxa are presented, thereby contributing to a syntaxonomic overview of the zonal vegetation. The syntaxonomy, ecology, structure, floristic composition, diversity, phytogeography and conservation of xeric, scrubland, grassland and cushion communities were explored and these vegetation types were related to main environmental factors, mainly altitude. In addition, the phytogeographical patterns of the xeric and dry puna flora were compared with other such ecosystems in Peru, Ecuador, Colombia, Bolivia, Chile and Argentina.

This research yielded six new species to science, which have been described and published separately (Montesinos-Tubée 2013a, 2014b; Montesinos-Tubée & Kool 2015; Montesinos-Tubée et al. 2016); these novelties are presented as an additional chapter.

The research had the following objectives:

1) to study the structure, species composition, cover, ecology and distribution of;
   a) the xeric and scrubland vegetation in the Arequipa province, South Peru under the influence of an extreme climatic event (Chapter 2) along an altitudinal gradient from 2020 to 3260 m;
   b) the prepuna scrubland vegetation communities found in the mountainous areas of North Moquegua at an altitude of 3470 and 3700 m (Chapter 3).
   c) the plant communities present in the puna of the mountains of North Moquegua comprising *Puya raimondii* patches, grasslands and chasmophytes in an altitudinal gradient of 3750–4500 m (Chapter 4).
   d) the superpuna plant communities found at high altitudes on the mountains and summits of North Moquegua (4450–4800 m) (Chapter 5).
2) to evaluate the importance of the plant communities by their diversity of endemic plant species in Moquegua (South Peru);
3) to analyze the phytogeographical affinities of the prepuna, puna and superpuna of North Moquegua in order to contribute to a better understanding of the distribution, origin, and diversity of its flora (Chapter 6) and
4) to describe the new species found in the study areas (Chapter 7).

The results provide a basis for conservation and biodiversity management in the region.
Syntaxonomic overview
This study represents the first attempt to classify the vegetation based on a quantitative data set from an entire mountain range in North Moquegua and the Arequipa province. The relatively high number of relevés allowed the presentation of a phytosociological overview of the vegetation.
The phytosociological classification of the vegetation of the Arequipa province and North Moquegua was based on floristic composition and species abundance and cover. Results revealed a total of one new class, five new alliances and twenty-four associations, which were distinguished and described according to the Zürich-Montpellier method (Braun-Blanquet 1979; Westhoff & Van der Maarel 1973; Wikum & Shanholtzer 1978).

Recognized and documented were: two new alliances and six new associations for the xerophytic communities; a new class for the prepuna which includes three new associations; two new alliances and seven new associations for chasmophytic vegetation; seven new associations for grassland and cushion communities of the puna and superpuna; and one new association of nitrophytic vegetation. In addition, thirty-five new subassociations were documented.

The vegetation survey resulted in the following syntaxonomic overview of the vegetation of the South Andes of Peru:

Xerophytic vegetation

I. *Opuntietea sphaericae* Galán de Mera & Vicente Orellana 1996
Oreocereo leucotrichi-Neoraimondietalia arequipensis Galán de Mera & Vicente Orellana 1996

A. *Ambrosio artemisioidis-Weberbauerocerion weberbaueri* Montesinos-Tubée, Cleef, Quipuscoa-Silvestre & Cleef 2015

1. *Weberbauerocereo weberbaueri-Browningietum candelaris* Galán de Mera & Vicente Orellana 1996
    - *haageocereetosum pluriflori* Montesinos-Tubée et al. 2015
    - *onoseridetosum odoratae* Montesinos-Tubée et al. 2015
    - *neoraimondietosum arequipensis* Montesinos-Tubée et al. 2015
2. *Senecioni yurensis-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015
    - *oenotheretosum verrucosae* Montesinos-Tubée et al. 2015
    - *chionopappetosum benthamii* Montesinos-Tubée et al. 2015
    - *ephedretosum americanae* Montesinos-Tubée et al. 2015
    - *eremodrabetosum schulzii* Montesinos-Tubée et al. 2015
3. *Euphorbio apurimacensis-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015
    - *kramerietosum lappaceae* Montesinos-Tubée et al. 2015
    - *jatrophetosum macranthae* Montesinos-Tubée et al. 2015
4. *Lycio distichi-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015
5. *Cantuo volcanicae-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015
6. *Paronychio microphyllae-Weberbauerocereetum weberbaueri* Montesinos-Tubée et al. 2015

B. *Neoraimondio arequipensis-Weberbauerocerion rauhii* Montesinos-Tubée et al. 2015

7. *Weberbauerocereo rauhii-Browningietum candelaris* Galán de Mera et al. 2009
    - *larreetosum divaricatae* Galán de Mera et al. 2011
8. *Armatocereo riomajensis-Neoraimondietum arequipensis* Galán de Mera et al. 2011
9. *Weberbauerocereo rauhii-Corryocactetum brevistyli* Galán de Mera et al. 2009
10. *Neoraimondio arequipensis-Browningietum viridis* Galán de Mera et al. 2011

C. *Corryocaction brevistyli* Galán de Mera & Vicente Orellana 1996

11. *Balbisio weberbaueri-Ambrosietum artemisioidis* Galán de Mera et al. 2011

12. *Aloysio spathulatae-Corryocactetum brevistyli* Montesinos-Tubée et al. 2015
- *oenotheretosum rubidae* Montesinos-Tubée et al. 2015
- *adesmietosum augusti* Montesinos-Tubée et al. 2015

13. *Weberbauerocereo weberbaueri-Corryocactetum brevistyli* Galán de Mera & Gómez Carrión 2001
14. *Corryocacto aurei-Browningietum candelaris* Galán de Mera & Vicente Orellana 1996
15. *Oreocereo tacnaensis-Corryocactetum brevistyli* Galán de Mera & Vicente Orellana 1996
16. *Grindelio bolivianae-Corryocactetum puquiensis* Galán de Mera & Gómez Carrión 2001
17. *Diplostephio tacorensis-Parastrephietum lepidophyllae: corryocactetosum brevistyli* Galán de Mera et al. 2003
18. *Weberbauerocereo rauhii-Corryocactetum brevistyli crotonetosum ruiziani* Galán de Mera et al. 2009

Prepuna vegetation (scrublands)

II. *Echinopsio schoenii-Proustietea cuneifoliae* Montesinos, Cleef & Sýkora 2012
Echinopsio schoenii-Proustietalia cuneifoliae Montesinos, Cleef & Sýkora 2012

D. *Salvion oppositiflorae* Montesinos, Cleef & Sýkora 2012

19. *Senecioni arnaldii-Exhalimolobetum weddellii* Montesinos, Cleef & Sýkora 2012
20. *Mostacillastro gracile-Chuquiragetum rotundifoliae* Montesinos, Cleef & Sýkora 2012
    - *phacelietosum pinnatifidae* Montesinos, Cleef & Sýkora 2012
    - *chuquiragetosum rotundifoliae* = subass. typicum Montesinos, Cleef & Sýkora 2012
    - *chaptalietosum similis* Montesinos, Cleef & Sýkora 2012
21. *Anredero diffusae-Diplostephietum meyenii* Montesinos, Cleef & Sýkora 2012
    - *diplostephietosum meyenii* = subass. typicum Montesinos, Cleef & Sýkora 2012
    - *bomaretosum ovatae* Montesinos, Cleef & Sýkora 2012

      variant of *Calceolaria pisacomensis*
22. Community of *Cylindropuntia rosea* and *Helogyne ferreyrae*
23. Community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*

Puna and superpuna vegetation

III. *Argyrochosmetea niveae* Gutte 1986
Salpichroetalia glandulosae Galán de Mera, Cáceres & González 2003

E. *Argyrochosmo niveae-Neowerdermannion peruvianae* Montesinos-Tubée, Cleef & Sýkora 2015 2015

24. *Plantagini sericeae-Plazietum daphnoidis* Montesinos-Tubée, Cleef & Sýkora 2015
25. *Phacelio secundae-Ribesetum brachybothryos* Montesinos-Tubée, Cleef & Sýkora 2015
26. *Neowerdermannio peruvianae-Festucetum weberbaueri* Montesinos-Tubée, Cleef & Sýkora 2015

F. *Hypochaerido mucidae-Loricarion graveolentis* Montesinos-Tubée, Cleef & Sýkora 2015

27. *Hypochaerido mucidae-Valerianetum nivalis* Montesinos-Tubée, Cleef & Sýkora 2015
28. *Paronychio ubinensis-Hypochaeridetum mucidae* Montesinos-Tubée, Cleef & Sýkora 2015
29. *Hypochaerido mucidae-Paronychietum muschleri* Montesinos-Tubée, Cleef & Sýkora 2015
30. Community of *Asplenium triphyllum* and *Polystichum orbiculatum*

G. *Saxifragion magellanicae* Galán de Mera & Cáceres 2002

31. *Saxifrago magellanicae-Leucherietum daucifoliae* ass. nov.

IV. *Calamagrostietea vicunarum* Rivas-Martínez & Tovar 1982
Parastrephietalia lepidophyllae Navarro 1993

H. *Azorello compactae-Festucion orthophyllae* Galán de Mera, Cáceres & Gonzáles 2003

32. *Parastrephio quadrangularis-Festucetum dolichophyllae* Galán de Mera, 2011
33. *Parastrephio lucidae-Festucetum orthophyllae* Galán de Mera, Cáceres & Gonzáles 2003
34. *Baccharido tricuneatae-Puyetum raimondii* Galán de Mera, Linares Perea, Campos de la Cruz & Vicente Orellana 2009
    - *senecionetosum ferreyrae* Montesinos-Tubée, Cleef & Sýkora 2015
    - *ageratinetosum sternbergianae* Montesinos-Tubée, Cleef & Sýkora 2015
    - *lupinetosum cuzcensis* Montesinos-Tubée, Cleef & Sýkora 2015
    - *calamagrostietosum heterophyllae* Montesinos-Tubée, Cleef & Sýkora 2015

35. *Sisyrinchio rigidifolii-Parastrephietum quadrangularis* Montesinos-Tubée, Cleef & Sýkora 2015
36. Community of *Misbrookea strigosissima* and *Stipa ichu*
37. Community of *Plagiobothrys humilis* and *Stipa ichu*
38. *Astragalo pusillii-Parastrephietum quadrangularis* ass. nov.
- *sisyrinchietosum trinervis* subass. nov.
- *baccharidetosum tricuneatae* subass. nov.
- *astragaletosum pusillii* subass. nov.

39. *Senecioni moqueguensis-Pycnophylletum molle* ass. nov.
- *mniodetosum pulvinatae* subass. nov.
- *senecionetosum tassaensis* subass. nov.
- *gentianelletosum primuloides* subass. nov.
- *arenarietosum acaulis* subass. nov.

40. *Calamagrostio trichophyllae-Azorelletum compactae* ass. nov.
- *mniodetosum pickeringii* subass. nov.
- *drabetosum soratensis* subass. nov.

I. *Calamagrostion minimae* Rivas-Martínez & Tovar 1982

41. *Baccharido caespitosae-Azorelletum diapensioidis* Montesinos-Tubée, Cleef & Sýkora 2015
42. *Astragalo minimi-Azorelletum diapensioidis* ass. nov.
- *wernerietosum melanandrae* subass. nov.
- *aciachnetosum pulvinatae* subass. nov.

V. *Anthochloo lepidulae-Dielsiochloetea floribundae* Rivas-Martínez & Tovar 1982
Anthochloo lepidulae-Dielsiochloetalia floribundae Rivas-Martínez & Tovar 1982

J. *Nototrichion obcuneatae* Galán de Mera, Cáceres & Gonzáles 2003

43. *Nototricho obcuneatae-Xenophylletum poposi* Galán de Mera, Cáceres & Gonzáles 2003
- *nototrichietosum erinaceae* subass. nov.
- *senecionetosum trifurcifolii* subass. nov.

44. *Poo aequiglumae-Xenophylletum dactylophyllum* ass. nov.
45. Community of *Senecio algens.*

VI. *Nitrophytic vegetation from unknown Class, Order and Alliance*
Community of *Tarasa nototrichoides* and *Urtica flabellata*

Further phytosociological research

More relevés, in particular of the xerophytic communities represented by *Oreocereo leucotrichi-Neoraimondietalia arequipensis,* are needed to better classify the alliance *Neoraimondio arequipensis-Weberbauerocerion rauhii*, which includes xerophytic associations of both northern and southern arid zones of the Arequipa province. Moreover, more relevés are also still needed from the southern slopes of the Upper Tambo River in North Moquegua, in order to be able to study the overlap between the prepuna and xerophytic scrublands and compare it with this overlap at 2900 m in the Arequipa province.
In addition, more phytosociological studies need to be done on the prepuna communities in North Moquegua; there are several new associations yet to be described from altitudes below 3500 m.

Azonal studies were not included in this research, but it can be expected that many azonal communities are yet to be described and published.

The limited accessibility of the specific study area throughout most of the year, together with high precipitation and thunderstorms, made the exploration of the higher superpuna (>4800 m) very difficult. Nevertheless, this description of the superpuna vegetation of North Moquegua is based on a relatively high number of relevés located below 4800 m.

Altitudinal zonation

The analysis of xerophytic, scrubland and grassland vegetation along an elevation gradient in South Peru showed an altitudinal zonation of vegetation series. Vegetation series are grouped into discrete zones corresponding to the xerophytic scrubland, the prepuna, the puna and the superpuna. This classification follows Rivas-Martínez & Tovar (1983), Huber & Riina (1997) and Kuentz et al. (2007).

The xerophytic communities of the Arequipa province (South Peru) can be found at an altitudinal range of 2020 to 2900 m. However, downslope on more southern slopes, it is expected to occur to about 1800 m.

Scrublands belonging to the prepuna in the Arequipa province have been found at 2900 up to 3260 m and exhibit an abundance of shrubs and columnar cacti. However, on the Moquegua mountain slopes, the upper limit of the prepuna is 3800 m. The puna vegetation, which occurs from 3800 to 4500 m, is classified into grassland, chasmophytic vegetation and patches of *Puya raimondii*. It is well characterized by the presence of tussock grasses in company with *Parastrephia* shrubs.

Finally, the superpuna is located from 4500 to 4800 m. The uppermost part of the superpuna is the subnival puna, where permanent or occasional snow cover can be found and vegetation becomes sparse and less diverse. Lower temperatures are characteristic of the superpuna; thunderstorms and heavy rainfall are frequent. Frost heaving and solifluction are common. Thus, altitude plays a key role in the distribution and diversity of species in South Peru.

The vegetation zonation is based on the altitudinal distribution of the major syntaxa found in this study. In Montesinos et al. (2012), the vegetation scheme was referred to the occurrence of the puna from 4300–4800 m. We later found that the limit of the puna is at 4500 m, since the combination of tussock grasses (*Festuca* spp.) and *Parastrephia* spp. shrubs changes drastically at 4500 m. Above this altitude, cushion formations dominate the landscape, tussocks are less frequent and short perennial and annual grasses are more abundant. This vegetation structure is typical of the superpuna of the study area. In Montesinos et al. (2012), the vegetation structure below 3300 m had not yet been analyzed and surveyed; Montesinos-Tubée et al. (2015), however, gave a clear overview of the vegetation structure in xerophytic environments. In figure 1, a revised new scheme for the vegetation zonation of the Arequipa province xerophytic communities and the Moquegua scrubland and grasslands is presented.

Table 1. Bioclimatic zonation with altitudinal data, Mean annual rainfall (mm), vegetation zones and characteristic syntaxa found in the study area. References are mentioned in the heading of the table.

Rain (mm)	**Altitudinal range**	**Bioclimate**	**Vegetation zone**	**Syntaxa**
Servicio Nacional de Meteorología e Hidrología del Perú (2009, 2013)	Montesinos et al. 2012; Montesinos-Tubée et al. 2015b chapter	(Rivas-Martínez & Tovar 1983; Rivas-Martínez 2004)	Huber & Ríina 1997; Kuentz et al 2007; Montesinos-Tubée et al. 2012, 2015, in press	Galán de Mera et al. 2009; Montesinos-Tubée et al. 2012, 2015, in press
>400 mm	> 4800 m	Cryorotropical; Subnival	Superpuna	*Anthochloo-Dielsiochloetea*
>400 mm	4500–4800 m	Cryorotropical	Superpuna	*Calamagrostietea vicunarum: Azorella compacta. Anthochloo-Dielsiochloetea*
300-450 mm	3800–4500 m	Orotropical	Puna (grasslands)	*Calamagrostietea vicunarum; Notholaenetea niveae. Puya raimondii* patches
200-350 mm	3100–3800 m	Orotropical, Supratropical	Prepuna (scrublands)	*Echinopsio-Proustietea*
< 100 mm	2000–3260 m	Mesotropical, thermotropical	Xerophytic, dry scrublands "Cardonales"	*Ambrosio-Weberbauerocerion; Corryocaction brevistyli*

* Modified from Montesinos et al. 2012

Vegetation Physiognomy

The diversity and density of growth forms varies with elevation. More diversity and density of cacti and succulents is clearly observed in the xerophytic communities of Arequipa province. Although the diversity and density of cacti decrease with altitude, a substantial percentage of cacti was found in the prepuna communities in North Moquegua. Xerophytic communities are well represented by annual herbs and grasses, succulents and few non-spiny shrubs. In contrast, the scrublands of the prepuna are well represented by spiny and thorny shrubs, annual grasses, ground rosettes, ferns and succulents. Towards higher altitudes as in the puna (3800–4500 m), spiny shrubs are mostly absent and replaced by resinous shrubs; cacti are less diverse and annual herbs and ground rosettes are more abundant. The superpuna is well characterized by the near absence of tall shrubs (except for *Parastrephia* spp.) and abundance of cushion plants, dwarf shrubs, ground rosettes and grasses. In the subnival areas, vegetation cover is sparse and frost occurs almost daily, leading to solifluction.

Floristic Composition and Diversity

Xerophytic communities from Arequipa province show patterns of species diversity that differ from those of xerophytic communities from the mountains of North Moquegua since Arequipa province receives less rain than North Moquegua (Servicio Nacional de Meteorología e Hidrología del Perú 2009, 2013). In the xerophytic communities, Montiaceae, Aizoaceae, Amaranthaceae, Boraginaceae, Euphorbiaceae, Fabaceae, Polemoniaceae, Polygonaceae and Portulacaceae are the most species-rich families of dry environments, which is the same trend as observed in other xerophytic environments (Roque & Cano 1999; Galán de Mera et al. 2009; Pinto & Luebert 2009). The xerophytic communities of Arequipa are unique because of the occurrence of the family Aizoaceae (*Tetragonia ovata*) and the family Zygophyllaceae (*Fagonia chilensis*), the occurrence of these families in arid ecosystems is corroborated by Shmida (1985).

Of the 257 genera encountered in our research in the Andean mountains of Moquegua, 185 occur in the prepuna (3400-3800 m), 148 genera in the puna (3800-4500 m) and 99 genera in the superpuna (4500-4800 m). The analysis was made based on herbarium collections by Montesinos-Tubée and on phytosociological relevés (Montesinos et al. 2012; Montesinos-Tubée et al. 2015b, Chapter 5).

In the study area, eighty-eight genera are unique to the prepuna, being Amaranthaceae, Boraginaceae, Cactaceae, Solanaceae and Verbenaceae, families that have the largest distribution of genera across the landscape at 3400–3800 m. Moreover, 19 genera only occur in the puna (Alstroemeriaceae: *Alstroemeria*; Apiaceae: *Niphogeton*; Asteraceae: *Ageratina*, *Coreopsis*, *Misbrookea* and *Plagiocheilus*; Caryophyllaceae: *Stellaria*; Dryopteridaceae: *Elaphoglossum* and *Polystichum*; Fabaceae: *Vicia*; Grossulariaceae:

Ribes; Lamiaceae: *Hedeoma*; Ophioglossaceae: *Ophioglossum*; Poaceae: *Triniochloa* and *Vulpia*; Polypodiaceae: *Campyloneurum* and *Polypodium*; Rosaceae: *Aphanes*, and Scrophulariaceae: *Limosella*). Finally, 20 genera occur only in the superpuna (Asteraceae: *Erigeron, Leucheria, Mniodes, Oritrophium, Werneria* and *Xenophyllum*; Campanulaceae: *Lobelia*; Cyperaceae: *Phylloscirpus, Trichophorum* and *Zameioscirpus*; Juncaceae: *Distichia* and *Oxychloe*; Montiaceae: *Montia*; Orchidaceae: *Myrosmodes*; Plantaginaceae: *Callitriche*; Poaceae: *Aciachne, Agrostis, Anthochloa, Dielsiochloa* and *Dissanthelium*).

The diversity of species found in the patches of *Puya raimondii* is considered to be the highest of all the studied ecosystems. A total of 132 vascular species were found only in the *Puya raimondii* communities at an altitude of 3850–4500 m. The high diversity can be attributed to nursing effects (Montesinos-Tubée et al. Chapter 5), moisture-retaining soil, and topography, since the plants establish on rocky slopes with deep crevices, as well as to other factors such as slope orientation and temperature. The species diversity is much higher than reported by Galán de Mera et al. (2009) for the Arequipa region and by Gutte (1986) for Central Peru. Also, cushion communities are known for their nursing environment (Catorci et al. 2014; Montesinos-Tubée 2015a).

Over 50 endemic vascular species are known to occur in the xerophytic communities of the Arequipa region, while in Moquegua, 58 endemic species have been reported. The endemism for the studied regions accounts for less than 15% of the total vascular flora.

Six species new to science were discovered, described and published: four belonging to the superpuna, one from the puna in Moquegua and one from Arequipa province (Montesinos-Tubée 2013a, 2014b; Montesinos-Tubée & Kool 2015; Montesinos-Tubée et al. 2016).

The vascular flora of North Moquegua is largely composed of natives and endemics. Three species whose occurrence in Peru had not been confirmed were found in both Moquegua and Arequipa during fieldwork; the species *Tephrocactus verschaffelti* (identified as *Austrocylindropuntia* sp. for the prepuna in Montesinos et al. 2012) is confirmed to be a new addition to the flora of Peru (Hoxey 2014), as is *Aphyllocladus denticulatus* from Chile, which was found in Arequipa province (Montesinos-Tubée et al. 2015a) and earlier also in Moquegua by Schwarzer et al. (2010). *Zephyranthes boliviana* is also a new addition to the flora of Moquegua, found by Montesinos et al. (2012) in the prepuna and confirmed by Montesinos-Tubée (2015b) as a new addition. These species were thought to only occur in Chile, Bolivia and Argentina.

Phytogeography

Because in Arequipa province only a limited altitudinal range was studied, Arequipa was excluded from the phytogeographical analysis. Only the data at genus level from Moquega were used, comprising mainly the dry puna biome. The phytogeographical composition of the flora of North Moquegua has a higher proportion of Tropical elements (ca. 48.6%) compared to that of other Andean floras. This characteristic is considered to be a consequence of the subhumid puna climate and high altitude.

The vascular flora of North Moquegua shows a close relationship with the puna of NW Argentina and the north of Chile. At the genus level, a number of similarities may be found between the páramos. In these locations, some shared genera have a high proportion of neotropical-montane elements. North Moquegua has a low humidity and is considered to be dry puna. As observed by Montesinos-Tubée (unpublished), that part of the region receives much more rain than the southern slopes of Moquegua department. This humidity is the result of proximity to Lake Titicaca in Puno, which can receive over 500 mm of rain per year. These climatic conditions make the North of Moquegua similar in genera composition to the high mountains of North Chile and NW Argentina.

Conservation implications

Since the late 1950s, the slopes of the Chili and Sabandía river valleys, San Lázaro and adjacent ravines in Arequipa province have been increasingly populated without supervision or control. This trend has generated a great loss of biodiversity. To date, there is no conservation program. Nevertheless, some organizations have made strenuous efforts to improve the conservation of the dry ecosystems of the Arequipa province by mass afforestation with native and introduced trees in order to counteract air pollution (Montesinos-Tubée 2012c) and by the creation of local botanical gardens.

Other issues concern desertification, which also causes the degradation of dry ecosystems. Major disturbances are related to processes such as volcanism, seismic activity and flash floods. The city of Arequipa is located in one of the most active volcanic chains of the Andes, with neighboring Misti volcano considered a serious threat (Sandri et al. 2014). Earthquakes are also frequent in the Arequipa region (Tavera et al. 2002); they may cause severe damage and rock avalanches on nearby mountain slopes. Although these natural disturbances can cause losses to certain ecosystems, at the same time they can create new natural habitats and restart succession. Nature conservation and supervision and control of urbanization are required, to avoid the loss of diversity in the Arequipa environs.

With regard to the mountains of North Moquegua, there is little detailed information about the extent and intensity of overgrazing and degradation in the Peruvian Andes (Lozada 1991). In recent decades, some agriculture has been intensified and soil degradation has increased due to the extensive use of pesticides and chemical fertilizers, and to overgrazing. The absence of soil conservation practices, together with overgrazing of the fragile Andean ecosystems, has led to severe rangeland degradation (Lozada 1991). More recently, Paduano et al. (2010) indicate that Lake Titicaca lies close to the lower limit of puna vegetation, which has been substantially modified by human activity.

Our vegetation research in northern Moquegua extends the knowledge of the syntaxonomy, floristic diversity and synecology of *Puya raimondii* stands in the matrix of chasmophytic and grassland vegetation. In addition to the impressive giant bromeliad *Puya raimondii,* many other endemic species are found in the newly described syntaxa, increasing the need for conservation schemes and measures. In recent years, the puna grasslands with *Puya raimondii* communities have been increasingly affected by grazing and human influence. The natural vegetation is being disturbed and *Puya raimondii* has regularly been cut down and burned to prevent livestock becoming ensnared in the spines of the giant rosettes.

In recent years, the superpuna communities have been increasingly affected by grazing and road construction. The natural vegetation is being disturbed and cushions of *Azorella compacta* have regularly been extracted for use as fuel. It is thought that part of the short grass species cover is caused by many years of overgrazing (examples Aciachne, Nasa?) At the same time, interviews with the local communities suggest that the pastures are being grazed in a way that prevents overgrazing. In addition to livestock, wild grazers, including vicuñas (*Vicugna vicugna*), viscacha (*Lagidium peruanum*), taruca (*Hippocamelus antisensis*) and suri (lesser rhea, *Rhea pennata*), are known to occur in the region. It is also known that the villagers harvest the wood of *Escallonia myrtilloides* for fuel and for use in festivities, causing gradual decline of their stands. This highlights the vulnerability of the flora and vegetation of the high Andes to human pressure, and requires further studies.

Fire has been regularly observed on several mountain slopes. These fires were probably started on purpose, as part of a festivity in June. Fortunately, due to the advice given by the author of this thesis to the local communities, this practice is now gradually decreasing (personal observation), and conservation programs have been started. Negative effects have been observed only in some grassland communities where livestock are abundant and species richness is relatively poor (communities of *Misbrookea strigosissima* and *Stipa ichu*, and *Plagiobothrys humilis* and *Stipa ichu*) and where tussock grasses are abundant and cover almost 70% of the ground.

In the near future, exploitation of natural resources will increase and may negatively affect the natural biodiversity.

On the basis of the research described in this thesis it is recommended to curtail the introduction of exotic tree species (*Eucalyptus rostrata, Pinus sylvestris* and *Cupressus macrocarpa*) for planted forests in the region and instead to use native species such as *Escallonia myrtilloides, Buddleja coriacea, Polylepis* spp. and *Kageneckia lanceolata*. The effect of introduced trees on native diversity in the tropics is well known, especially in the case of *Eucalyptus rostrata* (Paine et al. 2011). This exotic tree has been misguidedly proposed as an alternative for slope stabilization and erosion control in the Andes of Moquegua. Ground-covering lianas seem to be better for erosion control. Alternatives to the use of native trees are being encouraged but this makes it difficult to convince local communities about the dangers of using introduced trees in such fragile ecosystems. Native trees also grow more slowly than most exotic tree species.

Pennisetum clandestinum and *Trifolium amabile* are noted as becoming dominant in arable fields and can occasionally be found growing on paths and in grazed grasslands at increasing altitude, possibly because of climate change. Since global temperatures have been rising, in Moquegua it has been seen that *Pennisetum clandestinum* can occur as high as 4200 m, while *Trifolium amabile*, a native weed species, has been found as high as 4500 m. The great invasiveness of *Pennisetum clandestinum* (also known as *Kikuyuochloa clandestina*) in temperate and tropical zones (Cudney et al. 1993; Wilen & Holt 1996) is well known; the same applies to *Trifolium amabile* in Andean ecosystems (Thomas et al. 2010). Thus these species are having a large impact on natural diversity, replacing species and competing with natives and endemics, as seen in the Yunga district.

The conservation of the Moqueguan mountain environments should be prioritized for the preservation of these fragile and diverse ecosystems (Montesinos-Tubée 2011a). Biological and ecological guidelines have been proposed by Gutiérrez Tito (2012, 2013), who strongly recommends establishing a nature reserve in North Moquegua. The results of the research presented in this thesis can be used as a framework for the designation of nature reserves and nature conservation planning.

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Summary

The South American Andes mountain chain is 9000 km long. The great diversity in site conditions, due to the huge variation in altitude, topography and geology, has resulted in an impressing diversity of plant species and many different vegetation types. The tropical Andes are one of the world's biodiversity hotspots, but is under severe threat of increasing anthropogenic pressures.

The flora and vegetation of the mountains of North Moquegua, located in the Andes of southern Peru, has not yet been sufficiently studied and syntaxonomic knowledge about the plant communities in the area is still far from complete. The diverse plant communities found in South Peru include a large number of endemic species. A thorough description of the syntaxonomy and synecology of the vegetation would provide a firm basis for the protection of the Andean biodiversity.

This thesis presents an overview of plant communities from xerophytic and mountain environments. Four chapters present the results of a vegetation survey that used the Braun-Blanquet method. Ordination methods have been applied to study the relation between plant communities and environmental variables such as altitude, slope degree, rock and stone cover percentage, manure cover and grazing. A fifth chapter presents the results of a phytogeographical analysis in which we classified the phytogeographical elements and compared the phytogeography of Moquegua´s Andean mountains with other regions in South America.

Chapter 2 presents a phytosociological overview of the arid and semi-arid montane vegetation of the province of Arequipa in southern Peru. The xerophytic vegetation was studied after extreme rainfall which had promoted exceptionally lush vegetation and a high aboveground floristic diversity. We used TWINSPAN for classification and Detrended Correspondence Analysis for gradient analysis. PC-ORD was used to show the hierarchical similarity structure of the syntaxa, and to compare them with related communities in Peru and neighboring countries. We present a synoptic table, and describe the physiognomy, floristic composition, ecology and spatial distribution of the plant communities. In total, we recorded 187 plant species, including 50 endemics, in 196 phytosociological relevés distributed over 2030 km² at an elevation between 2020 and 3260 m. The relevés were assigned to three alliances in the class *Opuntietea sphaericae*. The vegetation consists mainly of native species of trees, shrubs, grasses, succulents, annual herbs, and ferns. The most diverse families were *Asteraceae*, *Cactaceae*, *Solanaceae*, *Malvaceae*, *Boraginaceae*, *Fabaceae*, *Poaceae*, *Amaranthaceae* and *Pteridaceae*. Within the class *Opuntietea sphaericae*, three alliances have been distinguished, two of which are new. The *Ambrosio artemisioidis-Weberbauerocerion weberbaueri* comprising six associations was recorded on barren hillsides between 2000 and 2900 m in the Arequipa city boundary zones. The *Corryocaction brevistyli* defines xerophytic scrub between 2700

and 3200 m in semi-dry regions bordering the puna grasslands. It contains the *Balbisio weberbaueri-Ambrosietum artemisioidis* and the *Aloysio spathulatae-Corryocactetum brevistyli* studied previously, all in need of further investigation as they lack sufficient number of diagnostic species. A unit clearly distinguished by *Weberbauerocereus rauhii* and *Neoraimondia arequipensis* is here described as a new alliance, *Neoraimondio arequipensis-Weberbauerocerion rauhii*. It grows in Andean valleys in dry regions (1100–2200 m), with abundant cacti accompanied by few xerophytes.

Chapter 3 presents an overview of the plant communities occurring in the prepuna of Moquegua (South Peru) at an altitudinal range between 3470 and 3700 m. For each plant community, information is given on physiognomy, floristic diversity, ecology and geographical distribution. The shrub vegetation on the slopes of the upper Tambo river valley includes annual herbs, grasses, cacti and ferns. In total, 151 vascular species have been recorded in forty-six relevés made at altitudes between 3470 and 3700 m. After classification with TWINSPAN, one class, one order, one alliance, three associations, five subassociations (including one variant) and two communities are distinguished. The class *Echinopsio schoenii-Proustietea cuneifoliae* comprises the order *Echinopsio schoenii-Proustetalia cuneifoliae*, and the alliance *Salvion oppositiflorae*, which occurs in the Prepuna dwarf scrubs. Within the alliance the following three new associations (with subassociations) have been distinguished: *Senecioni arnaldii-Exhalimolobetum weddellii* (thorny rosette-like dwarf shrubs), *Mostacillastro gracile-Chuquiragetum spinosae* (high cover of shrubs) and *Anredero diffusae-Diplostephietum meyenii* (high cover of clustered columnar cacti and patches of thorny shrubs). Two communities have been distinguished: *Cylindropuntia rosea* and *Helogyne apaloidea*, and the community of *Ophryosporus heptanthus* and *Escallonia myrtilloides*, which includes several introduced species growing on heavily grazed wet slopes. The basal communities with *Stipa ichu* and *Nassella asplundii* have also been identified. The most diverse families are Asteraceae, Poaceae and Cactaceae, followed by Solanaceae and Fabaceae. The vegetation includes endemic and native species and a few introduced species. Finally, DCA was used to interpret the correlations between environmental variables and species composition. The variation in species composition is best explained by altitude, inclination and vegetation cover.

Chapters 4 and 5 expand the approach presented in Chapter 2 by identifying the different plant communities occurring above 3800 m up to 4800 m.

First, in **chapter 4** the phytosociology and ecology of puna vegetation in twelve localities at altitudes between 3750 and 4500 m in northern Moquegua (South Peru) are studied. The study area has a pluviseasonal climate with summer rainfall. Using TWINSPAN, CANOCO 4.5 and PC-ORD, 157 phytosociological relevés were analyzed. For each community, the syntaxonomy, floristic diversity and relation with environmental variables are discussed. We recorded 210 vascular plant species belonging to 131 genera and 52 families. Three main vegetation types were distinguished: 1. chasmophyte vegetation composed of a great diversity of shrubs, dwarf shrubs, ferns and annuals, 2. *Puya raimondii* stands characterized by considerable species richness in shrubs, grasses and herbs, and 3. extensive puna grasslands influenced by grazing. The zonal vegetation of the supratropical and orotropical bioclimatic belts was represented by two phytosociological classes: *Argyrochosmetea niveae* (chasmophytes) and *Calamagrostietea vicunarum* (*Puya raimondii* and puna grasslands). Within the *Argyrochosmetea niveae* and *Salpichroetalia glandulosae*, the new alliances *Argyrochosmo niveae-Neowerdermannion peruvianae* and *Hypochaerido mucidae-Loricarion graveolentis* were distinguished, including six associations consisting of steep rock and crevice shrublands on lithosols. Within the *Azorello compactae-Festucion orthophyllae* (*Calamagrostietea vicunarum*) two associations with four subassociations and two communities were distinguished comprising grasslands and *Puya raimondii* stands. One association was described that belonged to the *Calamagrostion minimae*. The puna vegetation of Moquegua hosts many rare, endangered and/or protected plant species in Peru. The vulnerability of the flora and vegetation in the mountains of Moquegua is briefly discussed.

In **Chapter 5**, an overview is presented of the syntaxonomy and synecology of superpuna vegetation in 19 localities at altitudes between 4450 and 4800 m in northern Moquegua (South Peru). The study area has a pluviseasonal climate with summer rainfall. Using TWINSPAN, DCA and a dendrogram method, 153 phytosociological relevés were analyzed. For each community, the syntaxonomy, floristic diversity and relation with environmental variables are described. Four main highland vegetation types were distinguished: 1. slope and scree chasmophyte vegetation composed of shrubs, cushions, ground rosettes and grasses, 2. grasslands (grazed and ungrazed) characterized by great species richness in shrubs, cushions, ground rosettes, grasses and herbs, 3. vegetation of plateaus with cushions, shrubs, ground rosettes, herbs and grasses and 4. nitrophytic vegetation with high cover and low species richness. Within the vegetation of the orotropical and criorotropical bioclimatic belts four phytosociological classes were distinguished: *Argyrochosmetea niveae* (chasmophytic vegetation), *Calamagrostietea vicunarum* (grasslands with cushions), *Dielsiochloetea floribundae* (highland slopes and plateaus) and a nitrophitic community. One new association from rock and scree slopes was distinguished within the *Saxifragion magellanicae* (*Argyrochosmetea niveae*). Within the *Calamagrostion minimae*, which comprises grasslands with cushions and mat-forming plants, one new association with two subassociations could be distinguished. Within the grassland and cushion communities of the *Azorello-Festucion* (*Calamagrostietea vicunarum*), three new associations were described, comprising nine subassociations. In the *Anthochloo-Dielsiochloetalia* one association and also one association and community that had been described previously were distinguished. In addition, we distinguished the nitrophytic community of *Tarasa nototrichoides* and *Urtica flabellata*. In total our vegetation relevés comprised 172 vascular species belonging to 32 families. The puna vegetation of Moquegua hosts some rare, endangered and/or protected plant species in Peru. The vulnerability of the flora and vegetation in the mountains of Moquegua is briefly discussed.

Chapter 6 presents the results of a phytogeographical analysis of the Andean flora found in the mountains of Moquegua (based on Chapters 2, 3 and 4) and its relation to the neighboring puna of Peru and to other floras of the northern and southern Andes.
Of the total of 257 genera listed, 48.6% are predominantly distributed in tropical regions, less than 36.6% are distributed in temperate regions and 14.8% are considered to be cosmopolitan. The mountains of North Moquegua (South Peru) are divided into three major vegetation zones: prepuna (3400–3800 m), puna (3800–4500 m) and superpuna (4500–4800 m).
The Tropical elements represented by 48.6% includes several genera restricted to the central-southern Andes. This suggests that the Moquegua-related and Andean genera have considerable levels of speciation in these valleys. Many genera and more than half of the species have their northernmost distribution in South Peru (Central Andes), thereby underlining the strong relationships with central-southern South America (NW Argentina and North Chile), but emphasizing weaker relations with the puna-páramo elements. The data support the existence of a floristic disjunction in dry to arid environments in southern Peru, which separates a tropical dry flora north of this limit from a dry subtropical/warm temperate flora to the south. Although the proportion of elements differs among prepuna, puna and superpuna, their composition does not differ significantly from that in the entire Andean flora.

Moisture is the main driver of the phytogeographical regions. The actualized and revised phytogeography provides an important contribution to our knowledge of the spatial distribution of biodiversity in the Andes and will help planners to identify regions of high conservation relevance.

In **chapter 7** a number of species new to science have been described, *Paronychia ubinensis* Montesinos, from the Ubinas district and distributed at 4000–4500 m; *Senecio moqueguensis* Montesinos, *S. sykorae* Montesinos, *S. tassaensis* Montesinos, from the superpuna vegetation between 4500 and 4800 m, *Arenaria acaulis* Montesinos & Kool, from the Ubinas district and distributed at 4700 m and finally, *Tigridia arequipensis* Montesinos, Pauca & Revilla, from the xerophytic slopes of the Arequipa Province.

In **chapters 2–5** attention is paid to nature conservation issues, stressing the importance of protecting the fragile and diverse ecosystems of the Moqueguan mountains. The results of this vegetation survey can be used to prioritize the selection and assignment of nature reserves.

Samenvatting

De Zuid-Amerikaanse Andes vormt een negenduizend kilometer lange bergketen. De grote verscheidenheid aan standplaatsomstandigheden als gevolg van verschillen in hoogteligging, topografie, geologie en klimaat hebben geleid tot een grote diversiteit in vegetatietypen en een complexe biogeografie. De tropische Andes, een van de biodiversiteitshotspots (biodiversity hotspot) van de wereld, wordt sterk bedreigd door een toenemende menselijke druk.

De vegetatie van de Moquega Andes van Zuid-Peru, is onvoldoende onderzocht en de syntaxonomische kennis is nog onvolledig. In verschillende van de in Zuid-Peru aangetroffen plantengemeenschappen komt een groot aantal endemen voor. Een grondige beschrijving van de syntaxonomie en synecologie van de vegetatie is een belangrijk middel om de aanwezige megadiversiteit in de Andes te beschermen en de achteruitgang van soorten tegen te gaan.

In dit proefschrift wordt een overzicht van de plantengemeenschappen van halfwoestijn en hooggebergtemilieus gegeven. In vier hoofdstukken behandelen wij de resultaten van een vegetatiekundig veldonderzoek met behulp van de Braun-Blanquet methode. Met behulp van ordinatie is de relatie onderzocht tussen plantengemeenschappen en omgevingsfactoren als hoogteligging, hellingshoek, het percentage oppervlaktebedekking met rotsen en stenen, mest en begrazing. Na een plantengeografische analyse zijn de plantengeografische elementen geclassificeerd en is de plantengeografische samenstelling van het Andesgebergte van Moquega vergeleken met andere gebieden van de tropische Andes.

Hoofdstuk 2 geeft een vegetatiekundig overzicht van de aride en semi-aride montane vegetatie van de provincie Arequipa in Zuid-Peru. Het onderzoek vond plaats na extreme regenval, waardoor de vegetatie uitzonderlijk weelderig was en de bovengrondse diversiteit erg groot. Voor de classificatie is gebruik gemaakt van TWINSPAN en voor de gradiëntenanalyse van Detrended Correspondence Analysis (DCA). Voor de vergelijking van de beschreven plantengemeenschappen met verwante gemeenschappen uit Peru en de omringende landen is gebruik gemaakt van PC-ORD. Wij presenteren een synoptische tabel en beschrijven de fysionomie, soortensamenstelling, ecologie en ruimtelijke verbreiding van de plantengemeenschappen. In 196 vegetatieopnamen, gemaakt tussen 2020 en 3260 m hoogte en verspreid over 2030 km², zijn in totaal 187 plantensoorten waargenomen, waaronder 50 endemen.

De vegetatie bestaat voornamelijk uit inheemse boomsoorten, grassen, succulenten, eenjarige kruiden en varens. Families met de grootste diversiteit zijn *Asteraceae*, *Cactaceae*, *Solanaceae*, *Malvaceae*, *Boraginaceae*, *Fabaceae*, *Poaceae*, *Amaranthaceae* en *Pteridaceae*.

De vegetatieopnamen werden gerekend tot drie verbonden van de klasse *Opuntietea sphaericae,* waarvan twee nieuwe.

Het *Ambrosio artemisioidis-Weberbauerocerion weberbaueri* met zes associaties is beschreven van standplaatsen tussen de 2000 en 2900 m hoog gelegen, kale hellingen, grenzend aan de stad Arequipa.
Het *Corryocaction brevistyli* omvat xerofytische struikvegetaties, die op een hoogte van 2700 tot 3200 m hoogte voorkomen in semi-aride, aan de puna-graslanden grenzende gebieden. Het verbond omvat het *Balbisio weberbaueri-Ambrosietum artemisioidis* en het *Aloysio spathulatae-Corryocactetum brevistyli*. Beide associaties zijn onvoldoende gekarakteriseerd met diagnostische soorten en moeten daarom nog verder worden onderzocht.
Een duidelijk door de aanwezigheid van *Weberbauerocereus rauhii* en *Neoraimondia arequipensis* onderscheiden eenheid wordt tot een nieuw verbond gerekend, het *Neoraimondio arequipensis-Weberbauerocerion rauhii*. Dit verbond groeit op een hoogte van 1100 tot 2200 m in droge gebieden van de Andes, in cactusrijke valleien met enkele xerofyten.

Hoofdstuk 3 geeft een overzicht van de plantengemeenschappen die tussen 3470 en 3700 meter hoogte voorkomen in de prepuna van Moquega (Zuid-Peru). Bij iedere plantengemeenschap wordt informatie gegeven over de fysionomie, de soortensamenstelling, de ecologie en de geografische verbreiding. In de struikvegetatie op de hellingen van stroomopwaarts gelegen vallei van de rivier de Tambo, groeien naast struiken nog eenjarige kruiden, grassen, cactussen en varens. In totaal zijn in 46 vegetatieopnamen 151 vaatplanten gevonden. Na classificatie met TWINSPAN zijn een klasse, een orde, een verbond, drie associaties, twee subassociaties *typicum,* drie andere subassociaties, een variant en twee gemeenschappen onderscheiden. De klasse *Echinopsio schoenii-Proustietea cuneifoliae* omvat de orde *Echinopsio schoenii-Proustetalia cuneifoliae* en het verbond *Salvion oppositiflorae*, die in de dwergstruikvegetatie van de prepuna voorkomen. Binnen het verbond zijn de volgende drie nieuwe associaties (met subassociaties) onderscheiden: *Senecioni arnaldii-Exhalimolobetum weddellii* (doornige, rozetachtige dwergstruiken), *Mostacillastro gracile-Chuquiragetum spinosae* (hoge stekelige struikbedekking) en *Anredero diffusae-Diplostephietum meyenii* (hoge bedekking van gegroepeerde zuilvormige cactussen en pleksgewijs voorkomende doornstruiken). Verder zijn twee gemeenschappen onderscheiden: de gemeenschap van *Cylindropuntia rosea* en *Helogyne apaloidea* en de gemeenschap van *Ophryosporus heptanthus* en *Escallonia myrtilloides*, waarin verschillende geïntroduceerde soorten van intensief begraasde natte hellingen voorkomen. Daarnaast zijn nog de rompgemeenschappen van *Stipa ichu* en *Nassella asplundii* onderscheiden. Families met de grootste diversiteit zijn Asteraceae, Poaceae en Cactaceae, gevolgd door Solanaceae en Fabaceae. Behalve uit inheemse soorten, waaronder endemen, bestaat de vegetatie uit een paar geïntroduceerde soorten. Uit een gradiëntenanalyse met DCA bleek dat de soortensamenstelling een relatie heeft met de hoogteligging, de hellingshoek en de bedekking van de vegetatie.

In **hoofdstuk 4 en 5** wordt het vegetatieonderzoek uitgebreid naar een hoogte tussen de 3800 en de 4850 meter.

Hoofdstuk 4 geeft een overzicht van de plantensociologie en ecologie van de puna-vegetatie op twaalf locaties tussen 3750 tot 4500 m in Noord-Moquega (Zuid-Peru). Dit gebied wordt gekenmerkt door een klimaat met seizoensgebonden regenval (pluvioseasonal) in de zomer. De 157 vegetatieopnamen zijn geanalyseerd met behulp van TWINSPAN, CANOCO 4.5 en PC-ORD. Bij iedere plantengemeenschap worden de syntaxonomie, de soortsdiversiteit en de relatie met omgevingsfactoren besproken. In totaal zijn 210 vaatplanten uit 131 genera en 52 families gevonden. De vegetatie werd in drie hoofdgroepen verdeeld: 1) een vegetatie van rotsspleten (chasmofytenvegetatie) samengesteld uit een grote verscheidenheid aan struiken, dwergstruiken, varens en eenjarigen. 2) *Puya raimondii* – begroeiingen, gekenmerkt door een grote verscheidenheid aan struiken, grassen en kruiden, en 3) Uitgestrekt begraasd puna-grasland. De zonale vegetatie van de supratropische en orotropische bioklimaatzones zijn vertegenwoordigd door twee klassen: *Argyrochosmetea niveae* (chasmofyten) en *Calamagrostietea vicunarum* (*Puya raimondii* en puna-grasland). Binnen de *Argyrochosmetea niveae* en *Salpichroetalia glandulosae*, zijn de nieuwe verbonden *Argyrochosmo niveae-Neowerdermannion peruvianae* en *Hypochaerido mucidae-Loricarion graveolentis* onderscheiden, waaronder zes struikvegetatie-associaties van rotsen en rotsspleten op lithosolen. Binnen het *Azorello compactae-Festucion orthophyllae* (*Calamagrostietea vicunarum*) werden twee associaties met vier subassociaties en twee gemeenschappen onderscheiden van grasland en *Puya raimondii* begroeiingen. Binnen het *Calamagrostion minimae* werd één associatie beschreven. Puya raimondii (Bromeliaceae) vormt grote stekelige stamrozetten met een zuilvormige 4-5 m hoge bloeiwijze. Het is een van de nationale bloemen van Peru.

Hoofdstuk 5 geeft een overzicht van de syntaxonomie en de synecologie van de vegetatie in de superpuna tussen 4450 en 4800 m hoogte in Noord-Moquega (Zuid-Peru). Dit gebied wordt gekenmerkt door een klimaat met seizoensgebonden regenval (pluvioseasonal) in de zomer. De 153 vegetatieopnamen zijn geanalyseerd met behulp van TWINSPAN, CANOCO 4.5 en PC-ORD.

Bij iedere plantengemeenschap worden de syntaxonomie, de soortsdiversiteit en de relatie met omgevingsfactoren besproken. De vegetatie van het hooggebergte is in vier hoofdgroepen ingedeeld: 1) een uit struiken, kussenplanten, grondrozetten en grassen bestaande vegetatie van hellingen en puinhellingen met chasmofyten, 2) graslanden (zowel begraasd als onbegraasd) gekenmerkt door een grote verscheidenheid aan struiken, kussenplanten, grondrozetten, kruiden en grassen, 3) een vegetatie van plateaus met kussenplanten, struiken, grondrozetten, kruiden en grassen en 4) een stikstofminnende vegetatie met een hoge bedekking en een lage soortenrijkdom. Binnen de vegetatie van de orotropische en cryotropische bioklimaatzones konden vier klassen worden onderscheiden: *Argyrochosmetea niveae* (vegetatie van chasmofyten), *Calamagrostietea* *vicunarum* (grasland met kussenplanten), *Dielsiochloetea floribundae* (hellingen en plateaus van het hooggebergte) en een stikstofminnende (nitrofytische) gemeenschap waarvan nog onbekend is tot welke klasse hij gerekend moet worden. Binnen het *Calamagrostion minimae,* een graslandvegetatie met kussen- en matvormende planten, werd een nieuwe associatie met twee subassociaties onderscheiden. Binnen de grasland- en kussenplantvegetaties van het *Azorello-Festucion* (*Calamagrostietea vicunarum*) zijn drie nieuwe associaties met negen subassociaties beschreven. In de *Anthochloo-Dielsiochloetalia* zijn een nieuwe en een eerder beschreven associatie onderscheiden en bovendien nog een gemeenschap zonder syntaxonomische status. Tot slot zijn ook nog de nitrofytische gemeenschap van *Tarasa nototrichoides* en *Urtica flabellata* onderscheiden. In totaal zijn 172 vaatplanten uit 32 families aangetroffen. In de puna-vegetatie van Moquega komen zeldzame, bedreigde en/of in Peru beschermde soorten voor. De kwetsbaarheid van de bergflora en -vegetatie van Moquega wordt kort besproken.

Hoofdstuk 6 geeft de resultaten van een plantengeografische analyse van de bergflora van Moquega (gebaseerd op de hoofdstukken 2,3 en 4) en bespreekt de relatie daarvan met de aangrenzende puna van Peru en met andere flora's van het noorden en zuiden van de tropische Andes.

Van de 257 genera heeft meer dan 45% een overwegend tropische verbreiding, minder dan 40% heeft een verbreiding in de gematigde streken en 7% is kosmopolitisch. De bergen van Noord-Moquega (Zuid-Peru) in drie voornaamste vegetatiezones: prepuna (3400–3800 m), puna (3800–4500 m) en superpuna (4500–4800 m).

Meer dan 45% van de genera behoren tot het Andeselement. De meeste hiervan zijn beperkt tot de centraal-zuidelijke Andes. Dit suggereert dat de aan Moquega en de Andes gerelateerde genera in belangrijke mate in de aanwezige valleien zijn gespecialiseerd. Veel genera en meer dan de helft van de soorten bereiken hun meest noordelijke verbreiding in Zuid-Peru (Centrale Andes) en benadrukken hiermee de sterke verwantschap met centraal-zuidelijk Zuid-Amerika (NW Bolivia, en Noord en Centraal Peru), maar ook de geringere verwantschap met het Puna-Paramo-element. De resultaten bevestigen het bestaan van een disjunctie in de flora in de droge tot aride omgeving van centraal-zuid Peru, waarbij een tropische droge flora ten noorden van deze grens wordt gescheiden van een droge (sub)tropische/warm gematigde flora ten zuiden hiervan. Hoewel het aandeel van de elementen tussen prepuna, puna en superpuna verschilt, is de samenstelling niet wezenlijk anders dan die van de gehele puna flora.

De gematigde component is ook belangrijk en bestaat uit wijd verbreide gematigde genera op beide hemisferen, holarctische geslachten met belangrijkste verbreiding op het noordelijk halfrond, austraal-antarctische genera hebben hun hoofdverbreiding subantarctisch vooral en antitropische element bevat vooral subtropische geslachten, disjunct op beide hemisferen direct buiten de beide keerkringen.

Tenslotte is het aandeel van de kosmopolieten substantieel.

Vocht is de voornaamste factor bij het onderscheid van de plantengeografische gebieden. Dit geactualiseerde en herziene plantengeografische overzicht levert een belangrijke bijdrage aan de kennis van de ruimtelijke verbreiding van de biodiversiteit in de Andes en vormt een belangrijk hulpmiddel bij het lokaliseren van belangrijke natuurbeschermingsgebieden.

In **hoofdstuk 7** worden de volgende soorten voor het eerst beschreven: *Paronychia ubinensis* Montesinos, uit het Ubinas district met een verspreiding tussen 4000 en 4500 m hoogte; *Senecio moqueguensis* Montesinos, *S. sykorae* Montesinos, *S. tassaensis* Montesinos, uit de superpuna vegetatie tussen 4500 en 4800 m hoogte, *Arenaria acaulis* Montesinos & Kool, uit het Ubinas district op 4700 m hoogte en ten slotte *Tigridia arequipensis* Montesinos, Pauca & Revilla, van de droge hellingen in de provincie Arequipa.

Resumen

La cordillera de los Andes se extiende a lo largo de 9000 km en América del Sur. La gran diversidad en las condiciones del lugar, debido a la gran variación en la altitud, la topografía y la geología, ha dado lugar a una vasta diversidad de especies de plantas y muchos tipos de vegetación diferentes. Los Andes tropicales son uno de los puntos calientes de biodiversidad del mundo, pero está en peligro grave debido a las crecientes presiones antropogénicas.
La flora y la vegetación de las montañas del norte de Moquegua, que se encuentra en los Andes del sur de Perú, aún no se ha estudiado lo suficiente y el conocimiento sintaxonómico sobre las comunidades vegetales de la zona aún está lejos de ser completa. Las diversas comunidades vegetales que se encuentran en el sur de Perú incluyen un gran número de especies endémicas. Una descripción exhaustiva de la sintaxonomía y sinecología de la vegetación proporcionaría una base firme para la protección de la biodiversidad andina.
En esta tesis se presenta una visión general de las comunidades vegetales de ambientes xerófilos y de montaña. Cuatro capítulos presentan los resultados de un análisis vegetacional según el método de Braun-Blanquet. Métodos de ordinación se han aplicado para estudiar la relación entre las comunidades de plantas y las variables ambientales como la altitud, el grado de pendiente, porcentaje de cobertura por rocas y piedras, cubierta de estiércol y el pastoreo. En un quinto capítulo se presentan los resultados de un análisis fitogeográfico en el cual se clasifican nueve elementos fitogeográficos y se comparan datos de presencia de generos con respecto a otras regiones de América del Sur.

El **capítulo 2** presenta un panorama fitosociológico de la vegetación en zonas áridas y semi-áridas de montaña de la provincia de Arequipa en el sur de Perú. La vegetación xerófila se estudió después de la precipitación extrema que había promovido una exuberante vegetación y diversidad florística. Se utilizó TWINSPAN para la clasificación y análisis de correspondencias para el análisis de gradientes ambientales. PC-ORD se utilizó para mostrar la estructura jerárquica de la similitud de sintáxones, y compararlas con las comunidades descritas en otras regiones de Perú y de los países vecinos. Se presenta un cuadro sinóptico, se describe la fisonomía, composición florística, la ecología y la distribución espacial de las comunidades vegetales. En total, se registraron 187 especies de plantas, incluyendo 50 especies endémicas, en 196 relevés fitosociológicos distribuidos en 2.030 km^2 y a una altitud entre 2020 y 3260 m. Los relevés fueron asignados a tres alianzas en la clase *Opuntietea sphaericae*. La vegetación se compone principalmente de especies nativas de árboles, arbustos, gramíneas, plantas suculentas, hierbas anuales y helechos. Las familias más diversas fueron Asteraceae, Cactaceae, Solanaceae, Malvaceae, Boraginaceae, Fabaceae, Poaceae, Amaranthaceae y Pteridaceae. Dentro de la clase *Opuntietea sphaericae*, tres alianzas se han distinguido, dos de los

cuales son nuevas siendo la siguiente la que comprende nuevas asociaciones: *Ambrosio artemisioidis-Weberbauerocerion weberbaueri* con seis asociaciones registradas en laderas áridas entre 2000 y 2900 m en las zonas limítrofes de la ciudad de Arequipa. La alianza *Corryocaction brevistyli* se define dentro del matorral xerófilo entre los 2700 y 3200 m en regiones semi-áridas que bordean los pastizales de la puna y contiene las asociaciones *Ambrosio artemisioidis-Balbisio weberbaueri* y *Aloysio spathulatae-Corryocactetum brevistyli* que han sido estudiadas anteriormente y las cuales necesidan aún de una mayor investigación ya que carecen de suficiente número de especies diagnósticas. La unidad representada por *Weberbauerocereus rauhii* y *Neoraimondia arequipensis,* descrita aquí como una nueva alianza, *Neoraimondio arequipensis-Weberbauerocerion rauhii*, crece en valles andinos en regiones secas (1100 a 2200 m), con abundantes cactus y acompañados de unas cuantas xerófitas.

El **capítulo 3** presenta una visión general de las comunidades vegetales que se producen en la prepuna de Moquegua (sur de Perú) en un rango altitudinal entre los 3470 y 3700 m. Para cada comunidad vegetal, se da información sobre la fisonomía, la diversidad florística, ecología y distribución geográfica. La vegetación arbustiva en las laderas de la parte superior del valle del río Tambo incluye arbustos, hierbas anuales, gramíneas, cactus y helechos. En total, 151 especies vasculares se han registrado en cuarenta y seis relevés hechos a altitudes de entre 3470 y 3700 m. Después de la clasificación con TWINSPAN, una clase, un orden, una alianza, tres asociaciones, cinco subasociaciones (incluyendo una variante) y dos comunidades se distinguen. La clase *Echinopsio schoenii-Proustietea cuneifoliae* comprende el orden *Echinopsio schoenii-Proustetalia cuneifoliae*, y la alianza *Salvion oppositiflorae*, que ocurre en los matorrales bajos de la Prepuna. Dentro de la alianza, tres nuevas asociaciones (con subasociaciones) se han distinguido: *Senecioni arnaldii-Exhalimolobetum weddellii* (arbustos enanos espinosos), *Mostacillastro gracilis-Chuquiragetum spinosae* (alta cobertura de arbustos) y *Anredero diffusae-Diplostephietum meyenii* (parches con alta cobertura de cactáceas columnares y arbustos espinosos). Dos comunidades se han distinguido: la comunidad de *Cylindropuntia rosea* y *Helogyne apaloidea*, y la comunidad de *Ophryosporus heptanthus* y *Escallonia myrtilloides* que incluye varias especies introducidas que crecen en las laderas húmedas fuertemente pastoreadas. También se han identificado las comunidades basales con *Stipa ichu* y *Nassella asplundii*. Las familias más diversas son Asteraceae, Poaceae y Cactaceae, seguido de las solanáceas y leguminosas. La vegetación incluye especies endémicas y nativas y algunas introducidas. Por último, DCA se utilizó para interpretar las correlaciones entre las variables ambientales y la composición de las especies. La variación en la composición de especies se explica mejor por la altitud, inclinación y la cubierta vegetal.

Los **capítulos 4 y 5** amplían el enfoque presentado en el capítulo 2 mediante la identificación de las diferentes comunidades vegetales que se producen por encima de los 3800 m hasta 4800 m.
En primer lugar, en el capítulo 4 se estudió la fitosociología y ecología de la vegetación de la puna en doce localidades a altitudes entre 3750 y 4500 m en el norte de Moquegua (Perú sur). El área de estudio tiene un clima pluviestacional con lluvias de verano. Usando TWINSPAN, CANOCO 4.5 y PC-ORD, se analizaron 157 relevés fitosociológicas. Para cada comunidad, se discuten la sintaxonomía, la diversidad florística y su relación con variables ambientales. Se registraron 210 especies de plantas vasculares pertenecientes a 131 géneros y 52 familias. Tres tipos de vegetación fueron distinguidos: 1. vegetación casmófita, compuesta por una gran diversidad de arbustos, arbustos enanos, helechos y plantas anuales, 2. parches de *Puya raimondii* caracterizadas por una considerable riqueza de especies de arbustos, pastos y hierbas, y 3. extensos pastizales de puna influenciados por el pastoreo. La vegetación zonal de los pisos bioclimáticos supratropical y orotropical estuvo representado por dos clases fitosociológicas: *Argyrochosmetea niveae* (casmófitas) y *Calamagrostietea vicunarum* (*Puya raimondii* y pastizales de la puna). Dentro de *Argyrochosmetea niveae* y *Salpichroetalia glandulosae*, las nuevas alianzas *Argyrochosmo niveae-Neowerdermannion peruvianae* y *Hypochaerido mucidae-Loricarion graveolentis* se distinguieron, entre ellos seis asociaciones consistentes en matorrales de rocas y hendiduras pronunciadas en litosoles. Dentro del *Azorello compactae-Festucion orthophyllae* (*Calamagrostietea vicunarum*) dos asociaciones con cuatro subasociaciones con presencia de *Puya raimondii* y dos comunidades de pastizales fueron distinguidos. Una asociación se describe perteneciente a *Calamagrostion minimae*. La vegetación de la puna de Moquegua alberga numerosas especies de plantas raras, amenazadas y/o protegidas en el Perú. Se discute brevemente la vulnerabilidad de la flora y la vegetación en las montañas de Moquegua.

En el **capítulo 5**, una visión general se presenta de la sintaxonomía y sinecología de la vegetación de la superpuna en 19 localidades distribuidas a altitudes entre los 4450 y 4800 m en el norte de Moquegua (sur de Perú). El área de estudio tiene un clima pluviestacional con lluvias de verano. Usando TWINSPAN, DCA y un método dendrograma, se analizaron 153 relevés fitosociológicos. Para cada comunidad, la sintaxonomía, la diversidad florística y su relación con variables ambientales se describen. Cuatro principales tipos de vegetación del altiplano fueron distinguidos: 1. vegetación casmófita de pendiente y pedregales compuestos por arbustos, cojines, plantas en rosetas y pastos, 2. Comunidades caracterizadas por una gran riqueza de especies de arbustos, cojines, plantas en rosetas, pastos y hierbas, 3. la vegetación de mesetas con cojines, arbustos, plantas en rosetas, hierbas y pastos, y 4. Vegetación nitrofítica con alta cobertura vegetal y baja riqueza de especies. Dentro de la vegetación ocurrente en los pisos bioclimáticos orotropical y criorotropical se distinguieron cuatro clases fitosociológicas: *Argyrochosmetea niveae* (vegetación casmofítica), *Calamagrostietea vicunarum* (praderas con cojines), *Dielsiochloetea floribundae* (laderas montañosas y mesetas) y una comunidad nitrofítica. Una nueva asociación de laderas rocosas y pedregales fue distinguida en *Saxifragion magellanicae* (*Argyrochosmetea niveae*). Dentro de *Calamagrostion minimae*, que comprende los pastizales con plantas en cojines, se distinguió una nueva asociación con dos subasociaciones. Dentro de las comunidades de pastizales y plantas almohadilla de la alianza *Azorello-Festucion* (*Calamagrostietea vicunarum*), tres nuevas asociaciones se han descrito y las cuales comprenden nueve subasociaciones. En *Anthochloo-Dielsiochloetalia* dos asociaciones y una comunidad han sido descritas. Además, distinguimos la comunidad nitrofítica de *Tarasa nototrichoides* y *Urtica flabellata*. En total la vegetación se compone de 172 especies vasculares pertenecientes a 32 familias. La vegetación de la puna de Moquegua alberga algunas especies de plantas raras, amenazadas y/o protegidas en el Perú. Se discute brevemente la vulnerabilidad de la flora y la vegetación en las montañas de Moquegua.

Capítulo 6 presenta los resultados de un análisis fitogeográfico de la flora andina que se encuentra en las montañas de Moquegua (basado en los capítulos 2, 3 y 4) y su relación con la puna de otras regiones del Perú y otras floras de los Andes del norte y del sur de Sudamérica. Del total de 257 géneros considerados, 48,6% se distribuye predominantemente en las regiones tropicales, menos de 36,6% se distribuyen en regiones templadas y 14,8% se consideran cosmopolitas. Las montañas del norte de Moquegua (sur de Perú) se dividen en tres grandes zonas de vegetación: Prepuna (3400–3800 m), de la puna (3800–4500 m) y superpuna (4500–4800 m). El elemento Tropical representado por 48,6% incluye varios géneros restringidos a los Andes del centro-sur. Esto sugiere que los géneros relacionados con Moquegua y andinos tienen niveles considerables de especiación en estos valles. Muchos géneros y más de la mitad de las especies tienen su distribución más septentrional en el sur de Perú (Andes Centrales), subrayando así las fuertes relaciones con América del sur y centro-sur (NO Bolivia y norte y centro de Perú), pero haciendo hincapié en las relaciones más débiles con elementos de la puna-páramo. Los datos afirman la existencia de una disyunción florística para ambientes áridos en el sur de Perú, que separa una flora tropical al norte de este límite desde las zonas templadas subtropicales. Aunque la proporción de los elementos difiere entre prepuna, puna y superpuna, su composición no difiere significativamente de la de toda la flora andina.

La humedad es el principal factor de las regiones fitogeográficas. La fitogeografía actualizada y revisada ofrece una importante contribución a nuestro conocimiento de la distribución espacial de la biodiversidad en los Andes y ayudará a los planificadores a identificar regiones de alta relevancia para la conservación.

En el **capítulo 7** se han descrito varias especies nuevas para la ciencia: *Paronychia ubinensis* Montesinos, del distrito de Ubinas y distribuida a 4000–4500 m; *Senecio moqueguensis* Montesinos, *S. sykorae* Montesinos, *S. tassaensis* Montesinos, de la vegetación superpuna entre 4500 y 4800 m; *Arenaria acaulis* Montesinos y Kool, del distrito de Ubinas y distribuida a 4700 metros y, finalmente, *Tigridia arequipensis* Montesinos, Pauca y Revilla, de las laderas xerófilas de la Provincia de Arequipa.
En los capítulos 2–5 se brinda atención a las cuestiones de conservación de la naturaleza, haciendo hincapié en la importancia de proteger los ecosistemas frágiles y diversos de las montañas de Moquegua. Los resultados de este análisis de vegetación se pueden utilizar para dar prioridad a la selección y asignación de reservas naturales.

Acknowledgements

I wish to express my deeply appreciation to all those people that have supported me during the time I have been doing research in Moquegua and Arequipa.

Foremost, I am deeply thankful to my supervisor Prof. Dr. Karlè Sýkora, who taught me the beautiful science of phytosociology when I did the course "Vegetation Ecology and Systems Ecology" in 2008 and sooner I found a deep interest in doing my MSc Thesis with him. I very much appreciated his leadership, all his academic support, as well as his continues engagement with my research and the much-valued feedback he provided on the drafts of the articles. I feel so fortunate to have worked with you. Thank you for your trust when giving the chance to do this PhD.
When I met Antoine M. Cleef back in 2008, I felt incredibly lucky to have encountered one of the most influential scientists in phytosociology for South America. Antoine sooner became my second supervisor in my MSc and PhD theses. In numerous occasions he gave me the right advice, he was a great tutor in both professional and personal aspects, he has been always available for communication, attending my questions, guiding and encouraging me with enthusiasm and providing with great ideas.
I thank to my promotor Dr. Frank Berendse for his support and for reviewing and providing comments that helped to improve some chapters of this thesis.

The Nature Conservation and Plant Ecology chair group has been a very inspiring working environment for part of the time I stayed in Wageningen, thanks to the staff and PhD students: Ake, Anneke, Arina, Bingxi, Daan, Dick, Elmar, Flavia, Frans, George, Gerda, Gilian, Hanneke, Henk, Imma, Jan, Jasper, Jelmer, Joop, Juul, Koert, Liesje, Lisette, Maarten, Marije, Marinka, Marjolein, Maurits, Monique H., Monique W., Natalie, Peng, Petra, Philippine, Roy, Suzanne, Tess, Veronique, Wei and William, thank you for the enjoyable conversations during coffee breaks and the interesting presentations.

The Biosystematics chair group has also been a great working team during the time I spent at the Herbarium Vadense, thanks to the staff and PhD students: Carel, Diana, Erik, Folkert, Frans, Hendrikjan, Jan J., Kees Jan, Joost, Jos, Koen, Nico, Paul H., Rene, Richard, Susana, Theo and Wilma. I wish to give special thanks to Jan Wieringa who has been an inspiring scientist, guiding me through the process of understanding the challenging sections of plant systematics and preparation of manuscripts for the description of new taxa. Hans de Vries made the beautiful illustrations of *Paronychia* and *Arenaria*, I will always consider you as one of the best plant illustrator I have ever met. I also thank specially to Marc, Freek and Lars who gave me advices and renowned my deep interest in plant taxonomy. Thanks to Paul Maas for the important advices on the taxonomic manuscript of *Paronychia ubinensis*.
I would also like to thank the colleagues from other research groups for the enjoyable meetings: Catarina, Claudius, Cristina, Daniel, Frank, Frans, Karsten B., Herman, Jan, Klaas, Lennart, Linar, Lourens P., Laurens G., Madelon, Michael, Milena, Romila and Shenglai.
From Missouri Botanical Gardens, I wish to thank specially Dr. Ihsan Al-Shehbaz for encouraging me to work towards plant taxonomy. I also thank Roy Gereau, Peter Goldblatt, Peter Jørgensen, Carmen Ulloa, Jim Solomon, Henk van der Werff, John Pruski, Rosa Ortiz, Alba Arbelaez, Lauren Peters and Mary McNamara for their support during the visits I had to MBG on 2009 and 2013.

I am indebted to the DGFFS-SERFOR (Dirección General de Flora y Fauna Silvestre) from the Ministerio de Agricultura y Riego for the permits given to make botanical collections during the study. I am deeply thankful to Hugo de Vries Fonds (Amsterdam), NCP Group (Wageningen University, Netherlands), Michell & Company (Arequipa, Peru), Alberta Mennega Stichting (Utrecht, Netherlands), LEB Fonds and four anonymous persons for the financial support. I also thank Rentas & Servicios S.A.C. and Roberts Resersur for their support with transport logistics.

I am deeply thankful to the Herbario San Marcos (USM-UNMSM) staffs which have been very supportive during the past years. I am grateful to Mónica Arakaki, Cesar Arana, Severo Baldeón, Hamilton Beltrán, Mario Benavente, Berni Britto, José Campos, Asunción Cano, Susy Castillo, Magda Chanco, Blanca León, Maria Isabel la Torre, Betty Millán, Haydee Montoya, Eduardo Navarro, Wilson Ramirez, José Roque, Oscar Tovar, Huber Trinidad and Delsy Trujillo from the Museo de Historia Natural (Lima, Perú). I am very grateful to Carlos Ostolaza, Carmen Rosa Avendaño, Debora

Mac Donald, Guillermo Pino and Sidney Novoa from SPECS Society in Lima for their support during the conferences given. I also thank Ana Sabogal Dunin Borkowski for the teaching opportunity given at Pontificia Universidad Católica del Perú during 2011. Karen Ventura and Luis Huaman from Universidad Peruana Cayetano Heredia in Lima. Graciela Vilcapoma, Juan Carlos Ocaña, Arturo Granda and Mercedes Flores from Universidad Nacional Agraria la Molina (Lima). Anthony, Briggeth, Carmen, Cristian, Daniel R., Deysi, Din, Gleny, Italo R., Italo T., Jackelyn, Jessica, Károl, Marilu, Rafael, Raquel and Ximena from IMOD institute in Arequipa for their support during the lectures given and the enjoyable meetings. I thank Prof. V. Quipuscoa for his support on the identification of plant species. Washington Galiano and Percy Núñez from Universidad Nacional San Antonio Abad del Cusco and Isidoro Sánchez-Vega (Universidad Nacional de Cajamarca) gave assistance with identification of species. I also thank Percy Fernández, Francisco Lazo, Leopoldo Fernández, Humberto Pozo and Jorge Salinas Olivares from the Universidad Católica de Santa María de Arequipa.
Curators of the herbaria B, BR, CPUN, CUZ, F, HSP, HUPCH, HUSA, L, LPB, MO, MOL, P, USM, and WAG are thanked for the availability of their installations and plant collections. I also acknowledge the laboratory of Huasacache (UCSM) and UNALM for their availability for the soil analysis. I thank Shahina Ghazanfar for the opportunity to visit the KEW herbarium. Thanks to Rosa Isela Meneses, Angelica Velasquez and Stephan Beck for the access to LPB herbarium in La Paz, Bolivia. I am also grateful to the following people for support in the taxonomical identification of different species: René Chávez, Harvey Ballard, Alan Meerow, Carlos Lehnebach and Carola Volponi.

Joy Burrough corrected and improved the English of chapters 1–5, summary and introduction. Eusebio Quiroz Paz-Soldán, Franco Pedrotti, Ruben Sierra, John Watson, Marianne de Groot, Silvia Arroyo, David Hunt, Andres Moreira, Sebastian Teillier, Michael Dillon, Carolina Tovar and Roberto Kiesling helped with literature. Landsat data were provided courtesy of USGS EROS. Ben DeVries gave assistance on the map imaging development. Kati Zeballos designed the front cover and helped with improving the quality of images. Susana Montesinos, Matt Coler and Ruben E. Ventura gave suggestions in the toponymy of the native names of the mountains in Moquegua. I also thank the Geological National Service for the availability of maps from the studied regions.

Many helpers assisted in fieldwork including students, villagers, colleagues and friends. Special thanks to Luis Mondragón, Edwin Banegas, Edwin B. Ramos, Fabio Calisaya, Esteban Mamani, Juan Carlos Quiroz, Christian Pinto, Cristian Tejada, David Figueroa, Gabriel Aguirre, Christofer Macedo, José Antonio Quiroz, Juan Carlos Quiroz, Justa Quispe, Mario Callata, Elena Cuno, Gabriel Pastor, Meliza Rivera and the AGC-Lara managers, for their solidarity and recurrent field assistance.

I would like to thank the splendid people I met during the conferences in Tartu (Estonia), Perth (Australia) and Berlin (Germany): Gaia, Janice, Laco, Peter, Pedro, Sandra, Sergei, Siri Lie, Sula, Sabine, Thomas, David, Silvia, Patrícia, Robert and Jurr.

I also thank very specially to the fellow musicians I had the pleasure to perform music during my stay in Wageningen: Nima, Olivier and Charlotte (Animo band); Edward, Max, Roan, Tomas, Luigi, Pascal, Kealan, Katherine, Francisco, Wouter, Diego, Alex and David (assorted bands); Jimi, Johan and Ben (Caperune band); Coen, Todd, Frank, Nout and Kris (Skip Pickers band).
Jimi, Martine, Jane and James for the wonderful dinners and fun evenings! Coen, Danielle, Ellen, Lucia, Cristina, Alex and Bastian, thanks for the delightful music sessions and dinners at Weppa.

A la comunidad peruana en Wageningen: Alejandra, Alvaro, Bannie, Carolina, Claudia S., Claudia V., Cristian, Elena, Gabriela, Hugo, Jazmín, Karina, Laura, Marcelo, Martín, Milagros, Myluska, Patricia, Verónica y Yvan, gracias a ustedes por las amenas reuniones, divertidas fiestas y los almuerzos en el forum. Estoy eternamente agradecido a la familia Pinto Quintanilla en Socabaya (Arequipa) por su hospitalidad entregada durante los periodos de permanencia en su casa, sin dejar de mencionar a Don Ángel, María y a mi gran amigo y hermano Christian. Angelito fue un gran ayudante en casa. Pili y Killa generaron distracción y alegría en todo momento. Quiero dar un agradecimiento muy especial a la población y autoridades de las localidades de Exchaje, Camata, Pampilla, Yunga, Tassa, Pachamayo, Arapa, Sefincane, Coalaque, Querala, Matazo, Carmen Chaclaya, Ichuña, Santa Cruz de Oyo Oyo, Sefincane, Yanahuara y Tolapampa en el departamento de Moquegua por su hospitalidad y apoyo durante el trabajo de campo. A Gustavo Valcarcel quien nunca dudo en la investigación científica, por las oportunidades brindadas de publicar en revistas y periódicos en Moquegua, así como por gestionar posibles conferencias. Gustavo siempre valoró los importantes resultados de la investigación para el departamento de Moquegua. Asimismo, agradezco a mis amigos y amigas que me apoyaron de distintas maneras en las diferentes fases de investigación: Wanda, Lili Ann, Pierina, Deniz, Jackelin, Shirley, Rocio, Catalina, Lizzethe, Mariella, Tania, Cristina y Lizette. A Scarlet y familia, Javier Zea, Diego Linares, Mauricio y Fernanda, Luis Garcia, Julissa, Marco Delgado, Guillermo, Marcela, Carlos Bellido, Harolt, Holger, Marcos, Karina, Yovy, Karen y Cesar Rondón, Carlos Miranda, Gonzalo, Eduardo, Clau Murillo, Mónica Maldonado, Logina, Pablo Quintanilla, Josemaria, Lula, Ed y David, Neto Cuba, Mauricio Chirinos, Mireia, Warmi y Mac, Milagros y Leandro, Gonzalo y Gustavo Macedo, Doris y Maribel Cornejo, Michael Lanao, Pepe Rondón y Kent Chicalla. Asimismo, quiero dar un agradecimiento muy especial a Luis P. Mondragón y familia por su amistad eterna, las vivencias en Acarí y Arequipa. Luis me convenció de visitar Yunga un 14 de Setiembre del 2005 y quede maravillado por su geografía, lo cual fue el inicio de esta internminable y fascinante investigación, a ti te estoy eternamente agradecido compadre!

Also I want to express my deep acknowledge to the Alpine Garden Society members who visited Peru during March of 2014. I thanks very specially to Harry & Hannie Jans for their great friendship and the opportunity given to organize the fantastic tour in Peru. David & Celia Haselgrove thank you for my stay at your beautiful house in the south of England. John & Susan Ingham, I am deeply grateful for all your support during my stay in Oxford, lovely talks, great food, beautiful library and the fantastic tours we had around London and KEW gardens in 2014 and the survey we had in Amazonas and Huánuco (Peru) in 2015. Roger & Christine, thank you so much for the great talks we had and for the books, that mutual passion over every single plant in the field was outstanding, I also thank you for your suggestions and tips during my trip to Australia. I also want to thank Pat Bundy, Kris & Ingrid Raeymaeker, Hermien Challa-Wijnem, John Birks, Hilary & Austin Little, Kirsten & Lars Andersen, Andrew Ward, Roberta West, Joan Read, Martin & Anna Sheader, Sheena Hesketh, Christine McGreggor and Chris Barber. I also thank the Inca Legacy Tour operators, Jorge and the mayor of Tassa, Lucas for the boundless organization of the festivity we had in the town.

Thanks to Andrea Byrum, Kathryne Auerback, Ian Davies, Sara Friar, Kelty Carew, Karli Wagner, Victoria Forley, Stephan Gilchrist y Gavin D. Eagan from Edgewood College, Madison, Wisconsin (USA).

As an external PhD I partly dedicated to work in different jobs especially in the editorial sector in Peru. First I wish to express my thanks to Marc Sosef for the four-month job in the National Herbarium Nederland between 2012 and 2013. I want to thank the people that made possible the editorial work in Arequipa and Lima, for delivering their trust in the five books produced since 2011. I thank CDH-Gold Fields for the production of the book “Flora de los Andes de Moquegua. Etnobotánica de la Cuenca Alta de los Ríos Tambo-Ichuña”; I also thank to Tania Calienes and Fernando Bravo (Inca Legacy Cultural Society) for the edition and layout production. In Arequipa, I thank the Asociación Civil Patrulla Ecológica for the opportunities given to have produced the three books related to urban forestry, gardening and organic agriculture for the Arequipa city between 2011 and 2014; I thank Aloïs Patthey, Percy Ricketts, Renato Málaga, Andrés Chavez, Doris Tejada, Alejandro Casillas, Evelyn Carpio, Ruben Vela, Sergio Rivera and Marisol Valdivia. I also thank Cuzzi y Cía S.A. for the edition and layout of the book productions: Mario Cuzzi, Vera Quiñones and Kati Zeballos. A fith book was produced prior to the end of 2015, I thank Anglo American for the support on the publication of the Moquegua field flora book and la trastienda and Fernando Gygax (Impresa) are thanked for the design, layout and printing.

I also want to thank very specially to Peter Kothe, Mathilde Montesinos, Isabel & Richard Muirhead, Mark Muirhead and Pablo Muirhead families, Caterina Kothe, Juan Ignacio Bustamante, Alfonso Montesinos, Catalina Montesinos, Sebastian Montesinos, Alberto Montesinos, Helena & Henry, Francesca Montesinos, Gabriella & Andreas and Carlos Bünemann. I give special thanks to Maria Jose Tubée, Huub Tubée, Marja Tubée, Cees Schutter and M.C. Tubée.
Finally, but the most important, I thank to my family for their support. My father Bernardo, my mother Connie, my sister Susana, her husband Wilbert and my nephew Isabel have always been very supportive; throughout my life I have been blessed with your love and support, which made me who I am today.

The motivation and inspiration through all this years in the framework of the thesis would have been impossible without the beautiful classical compositions from Chopin, Beethoven, Mozart, Smetana, Rachmaninov, Verdi, Tchaikovsky, Saint-

Saens, ten Holt, Schubert and Bach that accompanied me all the time wherever I was, in the highlands of Moquegua, in Arequipa city or in the Netherlands.

Kati Zeballos made the cover of this thesis. Jimi and Susana were the best paranimphs, thank you!

Short Biography

Daniel B. Montesinos-Tubée was born on the 2nd of April 1982 in Caracas (Venezuela). Daniel attended primary and secondary school at Prescott and Champagnat in Arequipa, Peru (1987-1999). During the winter of 1999, he spent three months in Bremen (Germany) as part of a high school exchange.

From 2000 to 2006 he studied at Universidad Católica de Santa María (Arequipa, Perú) were he completed his BSc in Agriculture, in 2007 he obtained the degree of Engineer with the thesis entitled "Estudio botánico y taxonómico de la composición florística de cinco anexos de la Provincia General Sánchez Cerro, Dpto. de Moquegua, Perú" graded with *cum laude.* During his BSc university studies Daniel has done various internships, first in 2003 at the "Programa Chalaco" runned by the University of Piura in North Peru where he started his botanical and taxonomical specialization, later in 2004 he worked at the "Fundo Schuller" learning the procedures of coffee production and trading in Villa Rica (Central Peru). Finally in 2005, he did a three-month internship in landscape gardening in Milwaukee, Wisconsin (US).

He studied an MSc in Forest & Nature Conservation from 2007 to 2010 at Wageningen University obtaining his diploma in January 2011. He completed his thesis entitled "Plant Communities of the South Andes of Peru: Syntaxonomy and Synecology" and an internship at USM Herbarium in Universidad Nacional Mayor de San Marcos, in Lima, Peru. During this period, Daniel encouraged himself to start developing the checklist of the Moqueguan flora which later resulted in the description of several new species to science.

Upon completion of his MSc degree in 2011, Daniel took an external PhD position at the Plant Ecology and Nature Conservation Group at Wageningen University. He spent part of the time in Peru, where he worked in the editorial sector for almost four years producing five books that were published. He actively participated in different forestation programs sponsored by private and state companies which involved urban forestry projects in polluted cities. During his PhD, Daniel attended different conferences and international meetings (Estonia, Australia, Germany and Peru) presenting the results of his studies, which were twice awarded. Daniel visited twice the Missouri Botanical Gardens in St. Louis, Missouri during 2009 and 2013 as part of the taxonomical studies in which he analyzed the nomenclature and distribution of Caryophyllaceae and Asteraceae for Peru and South America. Between 2012 and 2013, he worked for the Biosystematics Group in Wageningen as part of the National Herbarium Nederland where he developed knowledge on classification of herbarium material upon geographical and nomenclatural status. Daniel also worked for Edgewood College, Madison, Wisconsin (US) as part of the project "Building Resilience: Improving Ecological, Social, and Economic Health – Alto Cayma" in Arequipa, Perú.

Daniel´s main scientific interests are in taxonomy of vascular plants from high mountain ecosystems, and the influence of structural and ecological processes on the plant communities.

List of publications

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Montesinos-Tubée, D.B. 2012. Fitosociología de las comunidades vegetales andinas de Moquegua, Perú. Libro de resúmenes del XIV Congreso Nacional de Botánica. 9–12 October 2012. Universidad Nacional de Trujillo, Trujillo, Perú.
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Montesinos-Tubée, D.B. 2008. Inventario Florístico de un transecto entre Pacaypampa (Provincia de Ayabaca) y Caxas (Provincia de Huancabamba), Departamento de Piura. Libro de Resúmenes del XII Congreso Nacional de Botánica. 18–21 September 2008. Universidad Nacional Amazónica de Madre de Dios, Madre de Dios, Perú.
Montesinos-Tubée, D.B. & Cornejo, D. 2008. Crecimiento y desarrollo de *Cobaea scandens* Cav. (Polemoniaceae) en las condiciones climáticas de la ciudad de Arequipa. Libro de Resúmenes del XII Congreso Nacional de Botánica. 18–21 September 2008. Universidad Nacional Amazónica de Madre de Dios, Madre de Dios, Perú.
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Unpublished work:

Montesinos-Tubée, D.B. 2010. Diccionario Enciclopédico Personal de las Plantas. Cayma, Arequipa, Perú. 697 pp.
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Additional contributions:

Ostolaza, C. 2014. Todos los cactus del Perú. Ministerio del Ambiente. Lima, Perú. 536 pp.
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Sabogal Dunin de Alegría, A., Watson, A.A., Teixeira Roth, V., Montesinos-Tubée, D.B., Santisteban Páez, C. & Vergara, K. 2011. Introducción a las Ciencias Experimentales. Ciencias Naturales. Formación Humanística y Científica. Pontificia Universidad Católica del Perú. Lima, Perú.

PE&RC Training and Education Statement

With the training and education activities listed below the PhD candidate has complied with the requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Review of literature (6 ECTS)

- Plant communities of mountain ecosystems in the tropics: taxonomy of plants and analysis and classification of the phytosociological classification of South American plant communities

Writing of project proposal (4.5 ECTS)

- The mountain vegetation of the South Andes of Peru: vegetation, ecology, phytogeography and conservation

Post-graduate courses (3 ECTS)

- Workshop for determination of Peruvian Cruciferae (Brassicaceae); National University of San Marcos, Lima, Peru (2012)
- Development training in ecological economic zoning for land use planning in the Arequipa region, South Peru; Regional Government of Arequipa, Peru (2013)
- National validation workshop of the categorization of wild flora species; National Forest Service and Wildlife, Ministry of Agriculture and Water, Lima, Peru (2015)

Laboratory training and working visits

- Analysis of South Peruvian flora for the update of taxonomy position and distribution of Asteraceae and Caryophyllaceae; Missouri Botanical Garden, University of Saint Louis, Missouri (2013)

Competence strengthening / skills courses (1.6 ECTS)
- Mobilising your scientific network; Wageningen Graduate Schools (2014)
- Information literacy including EndNote introduction; Wageningen UR Library (2014)

PE&RC Annual meetings, seminars and the PE&RC weekend (0.9 ECTS)
- PE&RC Weekend (2014)

Discussion groups / local seminars / other scientific meetings (5.9 ECTS)
- Medicinal plants and biodiversity of the Andes from Moquegua, South Peru (2012)
- Workshop of forestry and environment in the district of Cayma, Arequipa Province; Municipality of Cayma (2012)
- Environmental assessment, urban forestry and organic agriculture workshop with indigenous people in the project Nourish to Flourish - Alto Cayma (2012-2013)
- Seminar on sustainable development and forestation; Municipality of Arequipa, Peru (2013)
- Environmental assessment, urban forestry and organic agriculture workshop with indigenous people in the project building resilience, improving ecological, social and economic health - Alto Cayma (2014-2015)

International symposia, workshops and conferences (14.1 ECTS)
- Workshop-seminar: La Puna: aporte de la ciencia a su conocimiento; Lima, Perú (2011)
- The 56th International Symposium of the International Association for Vegetation Science, vegetation patterns and their underlying processes; Tartu, Estonia (2013)
- National Congress of Cactacea and Succulents (CONACyS); oral presentation; National University of San Agustin, Arequipa, Perú (2013)
- 57th Annual Symposium of the International Association for Vegetation Science: biodiversity & vegetation: patterns, processes, conservation; oral presentation; University of Western Australia, Perth, Australia (2014)
- Caryophyllales meeting; oral presentation; Freie Universität Berlin, Germany (2015)
- National Congress of Cactacea and Succulents (CONACyS); oral presentation; Pontificia Universidad Católica del Perú (2015)

Lecturing / supervision of practical's / tutorials (8 ECTS)
- Introduction to experimental sciences; Lima, Peru (2011)
- Introduction to phytosociology course; Lima, Peru (2011, 2015)
- Phytosociology course; Regional Government Arequipa, Arequipa, Peru (2013)
- Phytosociology course; La Convención, Cusco, Peru (2013)
- Phytosociology course; Lambayeque, Peru (2013)
- Ecology, environment and sustainable development course; Moquegua, Peru (2015)

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