Observations of *Blossfeldia liliputana* (Cactaceae) populations in Jujuy province (Argentina)

Bernd Panassiti[1], Osvaldo Ahumada[2], Stefan Porembski[1]

[1] University of Rostock, Institute of Biosciences, Department of Botany, Wismarsche Straße 8, D18051 Rostock, Germany

[2] Cátedra de Botánica General-Herbario JUA. Facultad de Ciencias Agrarias. Universidad Nacional de Jujuy. Argentina

Present address:
Bernd Panassiti
Laimburg Research Centre for Agriculture and Forestry
Laimburg 6 - Pfatten (Vadena)
39040, Auer (Ora)
BZ, Italy
Fax: + 39 0471 969 555
email: bernd.panassiti@provinz.bz.it

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Abstract

Blossfeldia liliputana Werdermann (Cactaceae) is known as the tiniest cactus with a distribution from southern Bolivia and to mid-west Argentina. Due to the inconspicuous habitus, little was known about the environmental effects on its distribution. The main objectives of this study were to describe the distribution of *B. liliputana* in Jujuy province, north-western Argentina, and to identify abiotic and biotic environmental parameters affecting the numerical abundance of *B. liliputana* populations.

Using existing information about ecology and previously described growth sites, we localized populations of *B. liliputana* and counted the number of above ground stems (hereinafter referred as "heads") within plots of 10 cm^2. A set of environmental data was derived from direct measurements, laboratory analysis and literature. Descriptive and multivariate statistics were used to infer habitat requirements.

We found seven locations with *B. liliputana* populations at Jujuy. Average populations size per plot ranged from four to 22 heads. *B. liliputana* prefers shaded rock crevices made of shale and slates and a annual mean temperature below 14°C and a annual precipitation lower than 200 mm. Seed dispersal by ants was not observed.

Although even after extensive field survey as much as seven locations were found, the cactus is not scarcely distributed rather the habitat is located in hardly accessible areas. Our findings suggest that *B. liliputana* is a habitat specialist adapted to extreme environments.

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Introduction

Blossfeldia liliputana Werdermann with a diameter of about 1 cm (exceptionally up to 4 cm) is considered as the smallest cactus in the world. Its distribution extends over a north-south distance of about 1700 km along the eastern Andean chains, starting from southern Bolivia (18° S, Dep. Cochabamba) to the central-west of Argentina (33° S, Prov. Mendoza) at elevations from 750-3400 m a.s.l. (Ritter 1980). A continuous distribution from southern Bolivia until the Argentinian province La Rioja with numerous populations of *B. liliputana* and scarce populations from San Juan until Mendoza is hypothesized (R. Kiesling, pers. comm.).

Due to the inconspicuous habitus, the cactus is difficult to find. *B. liliputana* camouflages itself in crevices of rock walls and might be easily overseen by the untrained eye. It can also be confused with lichen or mosses.

About five times larger than the aboveground part of the plant, the ramified roots efficiently use the small amount of accumulated soil (Fig. 1d). An individual plant of *B. liliputana* is characterised by a greenish flattened spherical body (Fig. 2a). The hermaphroditic flowers have reddish external tepals and cream-coloured internals ones. The fruit is about five mm long and reddish coloured, too (Fig. 2b). Moreover, *B. liliputana* lacks many other xeromorphic features expected for globular cacti, for example, a thickened cuticle, thickened outer cell walls and thickened hypodermal layers[2]. A detailed description of the morphology of the cactus is provided by Mendez (1983) for plants of Mendoza and Barthlott & Porembski (1996) using cultivated plants. Yet, as a result of both the inconspicuous habitus and the hardly accessible growth sites, little is known about ecology, population structure and habitat preferences of *B. liliputana*.

The study aim was to find existing *B. liliputana* populations in Jujuy province and record the population size. Habitat conditions such as climate, soil properties and the geomorphology were measured at the growth sites. Subsequent analyses on the population size of *B. liliputana* addressed

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59 the impact of these environmental parameters. Specifically, we asked: (1) how numerous are the *B.*
60 *liliputana* populations in terms of above ground plant parts (hereinafter referred as "heads"); (2)
61 what are favourable habitat conditions and which specific abiotic and biotic parameters influence
62 the population size; and (3) is there a need to specific conservation actions?

Figure 1: Habitat and habitus of *B. liliputana*: a) rock wall with a *B. liliputana* population; b) *B. liliputana* growing between shales; c) different development stages of *B. liliputana*; and d) single plant with branched roots.

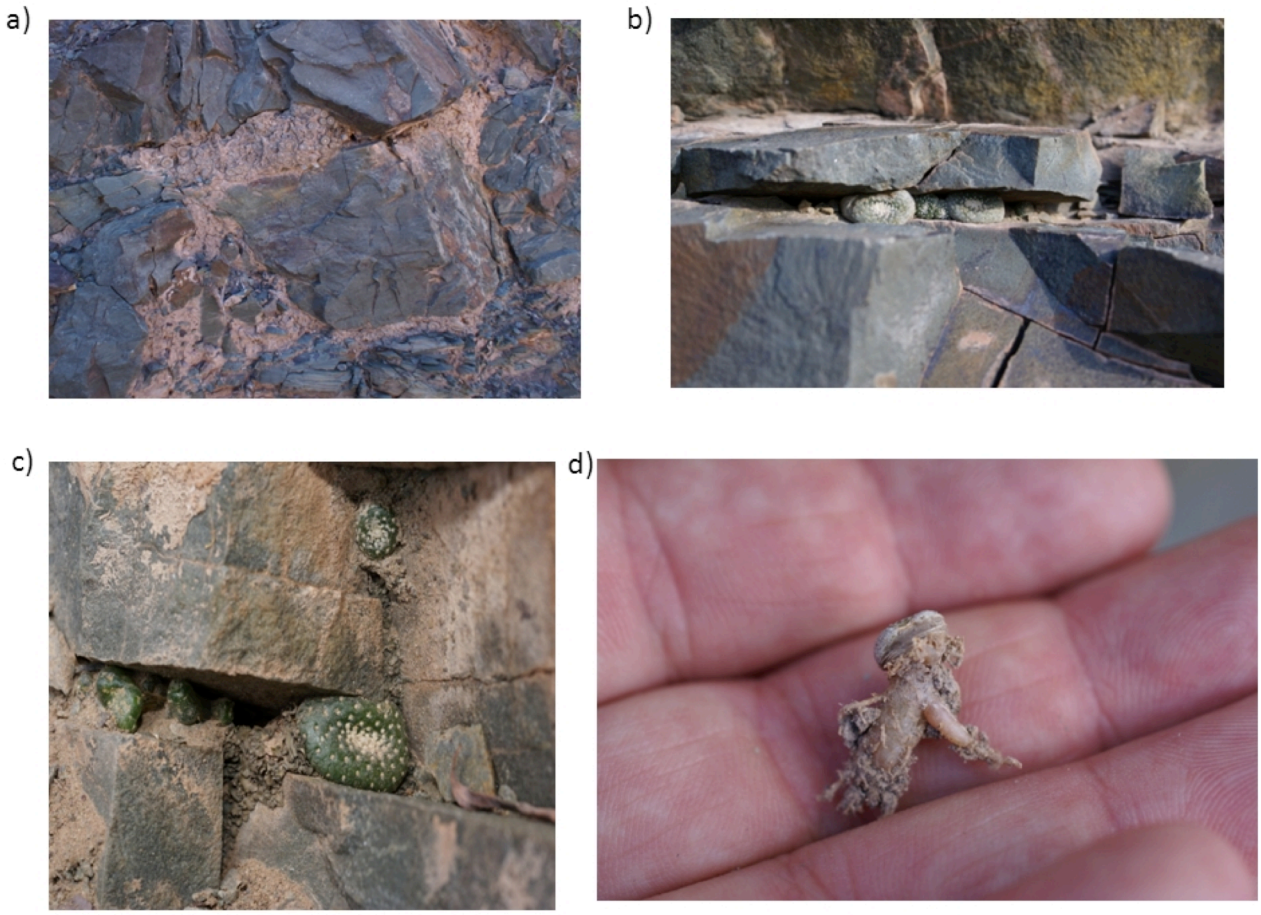

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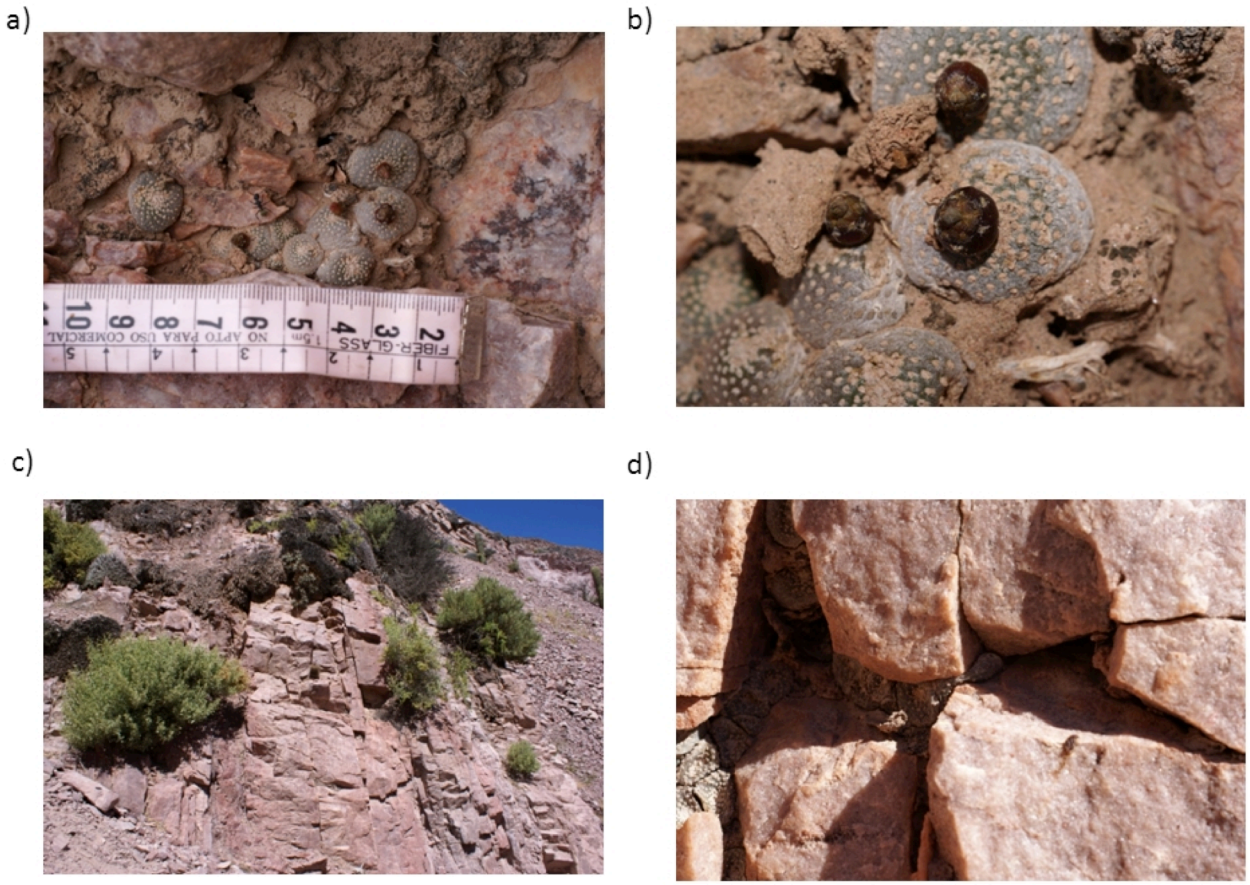
Figure 2: Habitat and habitus of *B. liliputana*: a) and b) *B. liliputana* with fruits; c) habitat of *B. liliputana* at the location 5 (Tunalito), characterised by fractured quarzites belonging to the Mesón Group (Cambrian). Acompanying species are xerophytic plants such as *Deuterocohnia* sp. and *Atriplex cordobensis* subsp. *grandibracteata* (shrub down left); and d) fig. 2c in detail, showing the efficient use of available crevices and gaps in the rock.



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Material and methods

Study area

The investigation took place in the northern part of Argentina, in Jujuy province from September 2007 to February 2008. From a phytogeographical point of view Jujuy political province is divided into five phytogeographical provinces: the Altoandina, Puna, Prepuna, Chaco and the Yungas (Cabrera 1976). The Prepuna extends along a canyon which is known as the "Quebrada de Humahuaca". The geographical layout of this canyon can be thought as a system of gorges. The Quebrada de Humahuaca reaches approximately from San Salvador de Jujuy to the villages Humahuaca and Tres Cruces in between 2.000 to 3.400 m a.s.l. Rising at the border to Bolivia, the river Rio Grande cuts through the Quebrada de Humahuaca.

Data collection

The study area in Jujuy province is hardly accessible, made of hills with steep slopes. Few locations of *B. liliputana* were recorded in Jujuy province. The Herbario JUA conserves one specimen with a rough description of the locality. Another two locations are known nearby the villages of Purmamaca and Angosto del Perchel - between Huacalera and Tilcara (Roberto Kiesling, pers. comm.). Barthlott & Porembski (1996) mention another location around 2600 m a.s.l. in the "Quebrada de Humahuaca" (Barthlott No. 10 037). We chose a plot size of 10 cm^2 to measure *B. liliputana* population size. Each above ground plant part ("heads") can be a single individual or a branch of a single plant. The number of recorded plots was depending on crevice size and clustering within crevices. Measurements of environmental and soil parameters are detailed in table 1. At each location a compound soil sample consisting of three sub-samples was collected using the grab-sampling method. We determined soil texture (according USDA) using the "finger test" (Schlichting et al. 1995; Sponagel 2005). Percentages of skeletal content and soil porosity were estimated. For two locations, soil laboratory analyses were conducted by "Laboratorio de analisis de suelos y aguas" (Convenio Universidad de Jujuy - Gobierno Prov. Jujuy; Ascasubi 200-B°Chijra,

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Jujuy). Compound soil samples were analyzed for organic material (Walkey & Black), pH (H_2O, suspension of soil/ water ratio 1:2.5), total nitrogen (Kjeldahl), extractable and available phosphorous (Bray-Kurtz), interchangeable cations (extraction with ammonium acetate, 1N at pH 7) and electrical conductivity (conductometry). Average annual precipitation and and average annual temperature were taken from Bianchi (1996).

We conducted temperature measurements of *B. liliputana* and surrounding habitat at a salient rock in gorge westwards from Tumbaya on 25th of February in 2008. Plant and rock surface temperatures as well as of the air temperatures were obtained almost simultaneously with two mercury thermometers. A centrally located, vivid, not dehydrated head was chosen to represent the colony. We measured air temperature with a distance of 120 cm to the chosen individual at a height of 70 cm. At a distance of six cm from the chosen head, the temperature of the rock surface was measured. Measurements were repeated every half hour from 9.30 am until 6.30 pm.

Table 1: Measured environmental parameters

Terrain parameter

exposition (°), inclination (°), altitude a.s.l. (m)

Soil parameter

- skeletal content (%), porosity (%), colour, texture
- organic material, pH (H_2O), total nitrogen (%), extractable and available phosphorous (mg/kg), interchangeable cations ($cmol_+/kg$), electrical conductivity (dS/m)

Statistical analysis

Since the "Q-Q-Plot" for graphical estimation as well as the "Shapiro-Wilk normality test" revealed non-normality of my data sets, for subsequent statistical analyses non-parametric statistics have been applied. To analyse the relationship between the environmental parameters and the population size of *B. liliputana*, the non-parametric ordination method "Non-M etrical Distance Scaling" (NMDS) was applied. In vegetation ecology, NDMS is considered as the most robust unconstrained

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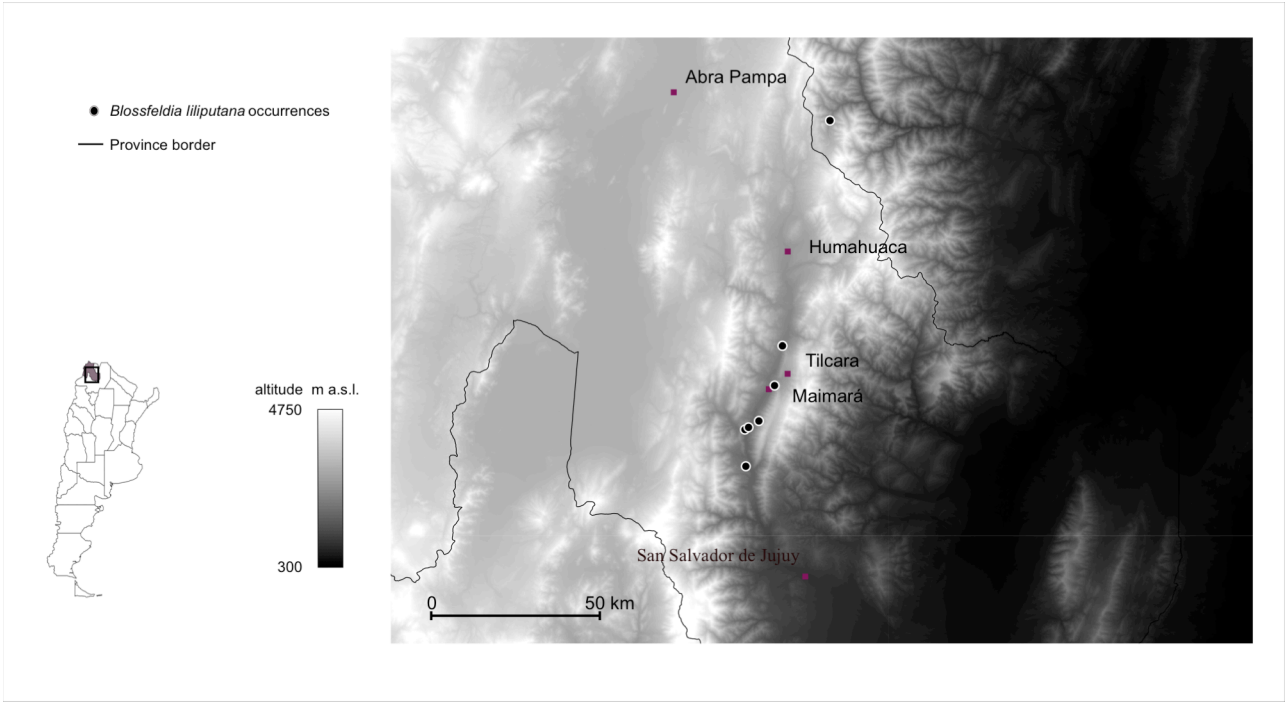
ordination method (Minchin 1987; Podani 2006). Statistical analyses were performed using R (R Development Core Team 2011).

Results

Population size

In total, we found in Jujuy seven locations with *B. liliputana* populations ranging from 2180 m to 2877 m a.s.l. (Fig. 3). The average number of heads per plot and location ranged from four to 22 (Tab. 2). A maximum number of 73 heads was counted.

Figure 3: Locations with *B. liliputana* populations in Jujuy province and one additional location in Iruya (Salta).



Abiotic and biotic effects on B. liliputana *populations*

We found *B. liliputana* populations in crevices between fractured rocks made of shale and slates belonging to the Puncoviscana Formation (Fig. 1b and c). The thin sediment layer hardly exceeds a depth of 10 cm. The formation of different soil horizons has not taken place. Table 3 shows a low

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carbon-to-nitrogen ratio indicating a fast processing of the organic material and thus, high nutrient availability. Moreover, high sodium and electric conductivity (EC) values - possibly caused by a bedrock made of fractured quartzites - suggest that the cactus is adapted to grow under rather saline conditions.

Table 3: Above ground plant parts ("heads") of *B. liliputana* per crevice.

Location		Number of above ground plant parts ("heads") per plot										
id	description	1	2	3	4	5	6	7	8	9	10	Mean
1	Purmamarca	5	3	5	22	11	16	-	-	-	-	10
2	Angosto de Perchel	3	10	1	60	52	3	-	-	-	-	22
3	Iruya	4	3	1	2	4	12	-	-	-	-	4
4	Tumbaya	1	6	10	4	1	1	5	11	4	3	5
5	Tunalito, Trail to Punta Corral	12	5	18	5	1	12	16	10	11	25	12
6	Purmamarca, Cruz (Entrance)	7	4	3	1	10	1	54	73	-	-	19
7	Tilcara, Maimará, Paleta del Pintor	26	13	3	16	11	-	-	-	-	-	14

Table 2: Soil analyses for two selected location with *B. liliputana* occurrences.

Locations	4	5
	Granulometric analysis	
Clay (%)	17.5	-
Slit (%)	20.0	-
Sand (%)	62.5	-
	Soil reaction	
pH (H_2O)	8.37	7.87
	Nutrients	
Organic material (%)	1.16	1.94
Organic carbon (%)	0.68	1.12
Total nitrogen (%)	0.08	0.08
C/N ratio	9	14
Extractable phosphorous	10	21.5
Available phosphorous	187	347
Carbonates Ca^{2+} and Mg^{2+} (%)	0.48	0.90
	Interchangeable cations	
Sodium ($cmol_+/kg$)	0.40	4.69
Potassium (cmol+/kg)	0.48	0.89
	Saturated paste	
EC (dS/m)	0.52	5.98
pH	8.27	7.40

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142 Air temperature ranged from 17°C to 26.6°C, rock temperature from 17.8°C to 36.8°C. Surface
143 temperatures of *B. liliputana* were similar to rock temperatures spanning from 17.8°C to 37.6°C.
144 Multivariate analysis indicated that a higher number of heads can be found where the annual mean

Table 4: Environmental parameter measured at locations with *B. liliputana* occurrences.

id	Temp (°C)	Preci (mm)	Altitude (m a.s.l.)	Expo (°)	Slope (°)	pH (H_2O)	Poro-sity	Skeletal content	Color	Texture
1	14.1	161	2200	280	40	7.46	1	3	grey	slightly sandy
2	13.0	148	2560	125	70	8.23	1	0	greyish-braun	sandy loam
3	18.3	350	2877	90	85	7.89	2	2	greyish-braun	loamy
4	14.3	200	2150	80	45	8.37	1	3	grey	sandy loam
5	13.8	141	2560	40	70	7.87	1	4	grey	sandy loam
6	14.1	161	2180	90	85	8.28	1	2	grey	slightly sandy
7	13.3	129	2620	330	80	7.79	1	1	reddish	sandy loam

145 temperature does not exceed 14°C and the annual precipitation is lower than 200 mm (fig. 4).
146 Finally, seed dispersal by ants was not observed during the study period.

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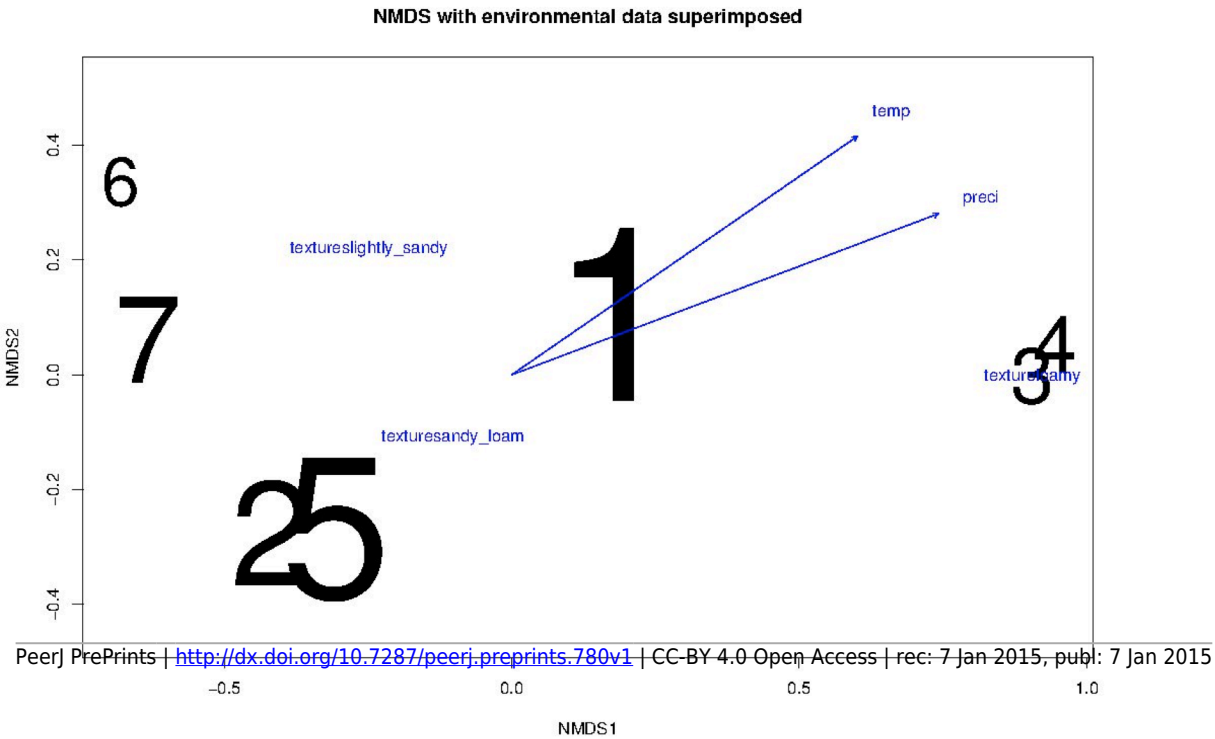
Figure 4: Non-metrical Distance Scaling to infer influence of environment on population size of *B. liliputana*.



Discussion

Habitat preferences

In total, we found six locations with *B. liliputana* populations in Jujuy province and one location in Iruya, Salta province. The bio-geographical distribution of *B. liliputana* in Jujuy province extends from Tumbaya northwards where the hills are covered with little vegetation. The vegetation is dominated by cushion-like Bromeliaceae (of the genus *Abromeitiella* sp.). The composition of the sediment of these hills can be characterized as being sandy-silty containing conglomerates. Larger rocks made up of boulders are quite scarce, exceptions can be found in the surroundings of Purmamarca and the nearby "Angosto del Perchel". Leuenberger (1998) found *B. liliputana* populations in altitudes between 1000 and 2550 m a.s.l. in Argentina.

Rock walls nearby Purmamarca represent an easily accessible growth site (Fig. 1a). These rocks belong to the so called Puncoviscana Formation. On the other side of the Rio Grande, between the northern parts of Tumbaya and southwards of "Angosto del Perchel", the rock formation of the Mesón group is predominating. This formation consists of silicate sandstone from the late Cambrian. *B. liliputana* populations were not growing in crevices of these sandstones. We could, however, find the cactus in crevices of rocks made out of fractured quartzites which are dated to this geological time period nearby "Tunalito" and between the villages Purmamarca and Maimará. At higher altitudes the geology completely changes from the Mesón group to the Puncoviscana formation, and occurrence of *B. liliputana* populations in fractured rocks made of shale and slates is more likely. But these sites are rather inaccessible and require alpine experience.

Except location 2, rock interstices are orientated north west and north east. The cactus, however, avoids direct exposure to solar radiation being plunged into crevices of the rocks walls which might function as a shelter against over-heating (Fig. 2d).

Previous studies of air and soil temperature have been conducted by different authors at growth

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sites of *B. liliputana* in different geographical regions. At a locality in La Rioja, Leuenberger (2008) measured 23°C for both air and soil temperature at a north-east facing rock at 9 a.m. Mendez (1983) measured an air temperature of 19°C - 25°C and a rock temperature of 21°C - 35°C. Moreover, he reported thermic values within a *B. liliputana* colony ranging from of 21°C - 41°C. Contrary to Mendez (1983), no large temperature differences between rock and plant surface were found. Barthlott & Porembski (1996) showed that *B. liliputana* has acquired a desiccation-tolerance (poikilohydry). Although *B. liliputana* grows mainly near permanent rivers (with frequent nocturnal condensation), observations in our study indicate that the cactus may survive longer periods of drought.

Dispersal

Wind is assumed to be the principal way of dispersal (anemophily). Ants may function as additional seed dispersers (myrmecochory). An arillus and hairy appendices support this hypothesis (Barthlott & Porembski 1996). Seed dispersal by ants, however, could not be observed in the during this study.

Conservation

Due to easy access to rock walls nearby Purmamarca, human collecting activities have extremely reduced the populations of *B. liliputana* in this area. However and in agreement with Leuenberger (1998), we argue that *B. liliputana* faces no immediate risk of extinction.

Conclusions

Altogether, the environmental conditions of the locations indicate that *B. liliputana* is a habitat specialist adapted to extreme environments. It prefers shaded rock crevices made of shale and slates. From a conservation point of view, the cactus is not scarcely distributed rather the habitat is located in hardly accessible areas.

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