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RESEARCH PAPER

Species richness, diversity and human activities in an elevation gradient of a high-ecosystem in Lagunas Huascoaltinas, Atacama Region, Chile

Doris Sanhueza, Marcelo Miranda, Miguel Gómez, and Cristian Bonacic
Facultad de Agronomía e Ingeniería Forestal, Pontificia Universidad Católica de Chile, Casilla 306-22, Santiago, Chile

Abstract

D. Sanhueza, M. Miranda, M. Gómez, and C. Bonacic. 2009. Species richness, diversity and human activities in an elevation gradient, a high-ecosystem, Lagunas Huascoaltinas, Atacama Region, Chile. Cien. Inv. Agr. 36(3):411-424. The relationship between species richness, diversity and grazing frequency along an altitudinal gradient (1900-3400 m) of an Andean ecosystem indicates that there is an intense human pressure on vegetation use. To identify the vascular flora and its conservation, 20 sites were sampled in two visits during 2006. We identified 79 taxa, including 62.03% native species, 22.78% adventitious and 8.86% endemic (the remaining 6.33% was identified only at the genus level). Some genera were underrepresented. We also observed latitudinal limits (*Alstremeria andina*), monotypic genera (*Geoffroea, Kurzamra, Phragmites*, *Tessaria* and *Salix*) and monogeneric families (Buddlejaceae, Ephedraceae, Equisetaceae, Malesherbiaceae, Salicaceae and Oxalidaceae). Moreover, we found differences in the species distribution patterns during periods of grazing use and identified statistically significant differences in the species richness ($p < 0.001$), diversity ($p = 0.010$) and grazing frequency ($p = 0.047$).

Key words: Altitudinal gradients, species richness, vegetal diversity, human pressure, Andean wetlands ecosystems.

Introduction

The High Andean eco-Region, which lies between the Copiapó River and the Osorno volcano, corresponds to an altitudinal strip that spans the tree vegetation limit to the higher vegetation limit. It is generally found in river basins that are separated by high mountain chains, which allows for the development of endemisms (Hoffmann *et al*., 1998).

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Corresponding author: dpsanhue@puc.cl.

Lagunas Huascoaltinas (28º44` S; 69º 53` W), the site under study, is located in the Sub-Andean floor or puna (2.700 and 3.500 m high), where the most common species are bush-like (*Adesmia hystrix, Ephedra breana, Viviania marifolia*), and *Jarava chrysophylla* is the most common graminea (Squeo *et al*., 1994; Hoffmann *et al*., 1998). In 1996, the Corporación Nacional Forestal de Chile (CONAF) declared the areas of Laguna Grande, Laguna Chica and Laguna Valeriana to be priority sites. The National Environmental Commission of Chile (Comisión Nacional de Medio Ambiente de Chile, CONAMA), through biodiversity conservation programs and priority site identification, established this zone as a Category of Some Conservation Priority in 2003. Nevertheless, there have not yet been studies evaluating the effect of anthropic use on the sector flora. This priority site represents a transitional zone between the tropical and Mediterranean pluviometric regimes (Di Castri and Hajek, 1976), where ecological and historical processes have allowed the evolution of a characteristic mixed biota (Morrone, 2004).

Squeo et al. (1994) characterized the High Andean vegetation around 30º S in the Doña Ana mountain chain in the Region of Coquimbo. This study provided a global characterization of the flora and vegetation of the desert Andes. Arroyo et al. (1988, 1984) described the flora in the area of Lagunas Huascoaltinas, recording the habitat and new altitudinal ranges of the species. In this site, as in other places in Chile, the anthropic activities have progressively and irreversibly degraded the biological communities, leading to the loss of soil covers and making it more difficult for these sites to be used (Arroyo et al., 1988; Primack et al., 2001; Villagrán and Castro, 2003).

Goats are exotic mammals that have received attention from scientists because of their negative impacts on the natural ecosystems in which they have been introduced (Alvarez-Romero and Medellín, 2005). The Laguna Grande sector (Figure 1) is visited during the summer pastures by breeder who extensively rely on goats, which consume the vegetation of the zone. People also use the vegetal resources to build houses and pens and to extract medicinal plants. The domestic goats considerably affect the herbs and bushes, leading to deforestation and the reduction of resources used by the native fauna (Jaksic, 1998).

The objective of this work was to determine the relationship between variable richness, the Shannon diversity index and the number of grazed species, while considering anthropic use and the type of existing habitat in the studied altitudinal gradient.

Materials and methods

Area of study

The work was carried out along an altitudinal gradient from the town of Junta de Valeriano (28º 53` S; 70º 02`W) to Laguna Grande (28º 43`S; 69º 54`W). This region is approximately 1900 to 3400 m high and lies in the Andean chain of the Third Region of Atacama, Chile (Figure 1).

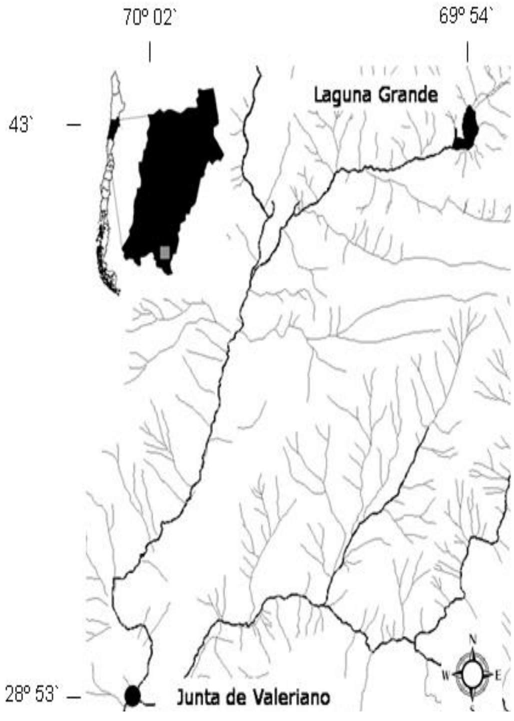

Figure 1. Map of the studied area, "Lagunas Huascoaltinas", Atacama Region, Chile.

This geographical area is in the Region of the High Andean Steppe of the arid and semiarid zone of the Andes Mountain Chain (Gajardo, 1994). According to Di Castri and Hajek (1976), the site under study is located in a desert climate zone and has winter rains that provide the area with some features of a Mediterranean climate. Therefore, the antitropical variant of the area indicates a transition towards the zone of the Mediterranean climate, with a warm thermal regime and a mean annual temperature ≥ 21ºC. (Luebert and Pliscoff, 2006). The mean precipitation accrued over 30 years (1961-1990) in the Vallenar aerodrome (28°35' S; 70° 46' W; 469 m high) was 31.6 mm per year.

Methodology

Two expeditions to the area under study were made in February-March and November-December of 2006. During these expeditions, we sampled 20 points, which were established with three 50 meter long parallel linear transects separated by 50 m. These transects were placed from the Cazadero river shore, and the vegetal communities were sampled on the river shores. The expedition in February-March corresponded to the summer season, after summer pasture, when there is intensive use of the vegetation in the high zones of the altitudinal gradient. The second expedition in November-December corresponded to the winter season, before the summer pasture and when the vegetation use is concentrated in the low zones of the gradient. This cattle activity allowed us to divide the gradient into two sectors: the winter use zone (intervened during the whole year), located between 1900 and 2600 m high, and the summer use zone (only intervened during the summer pastures), located in the high part of the gradient between 2700 and 3400 m high.

To generate a floral list of the area under study, all of the vegetal species that were found were sampled and photographed in their habitat for further identification.

In each transect, we recorded: (1) the richness of species, corresponding to the total number of species within the 50 m long transects, and (2) the abundance and frequency of grazed species (action made by animals as they cut and eat vegetation), which corresponded to all of the species that touched the transect every 5 m. The grazed species were determined through the presence or absence of irregular cuts on their leaves or stems.

Statistical analysis

This information allowed us to estimate the Shannon biodiversity index (H) as:

$$H = \sum_{i=1}^{S} \left(\frac{n_i}{n} * \ln\left(\frac{n_i}{n}\right)\right)$$

where, n is the number sample individuals, n_i is the number of individuals belonging to the ith species and S is the number of species in the sample.

Subsequently, the richness results, the Shannon biodiversity index and the frequency of grazed species were compared, considering two ranges of anthropic use (n_{winter} =1 8; n_{summer} = 22) and two types of habitat ($n_{meadows}$ = 10; $n_{hillsides}$ = 10), through the non-parametric test of Kruskal-Wallis multiple ranges analysis (differences among multiple independent groups). The relationship between the number of grazed species and the Shannon biodiversity index for every range of use and type of habitat was determined using a simple linear regression model.

Results

During both seasons, 79 taxa of the vascular flora were identified (74 at the species level; 5 at the genus level) (Table 1). During the first expedition, 64 taxa were recorded, and 53 were recorded during the second expedition. These taxa include 66 genus and 40 families in total. The most frequent species were: *A. hystrix*, *Buddleja suaveolens*, *Cortaderia rudiuscula, E. breana*, *Fabiana imbricata*, *Haplopappus baylahuen*, *J. chrysophylla*, *Schinus poligama*, *Senecio an-*

Table 1. Flora inventory, frequency of species and frequency grazing in an elevation gradient during sampling over two seasons in the Lagunas Huascoaltinas, Atacama Region, Chile, 2006.

Familie/Specie	Forms of growth[1]	Conservation status	Biogeographical origin	Frequency[1], %		Frequency[2], %	
				Species	Grazed species	Species	Grazed species
Alstroemeriaceae							
Alstroemeria Andina Phil.	HP	FP	N	0	0	5	0
Anacardiaceae							
Schinus Polígama (Cav.) Cabrera	Ab	FP	N	30	15	50	35
Apiaceae							
Apium Panul (Bertero Ex DC.) Reiche	HP	FP	N	5	0	5	0
Asteraceae							
Baccharis Sagittalis (Less.) DC	HP	IC(VU?)	N	15	10	5	0
Baccharis Salicifolia (Ruiz Et Pav.) Pers.	Ar	FP	N	25	20	20	15
Baccharis Tola Phil.	Ar	IC(FP?)	N	5	0	5	0
Chaetanthera Lanata (Phil.) I.M. Johnst.	HP	FP	N	0	0	5	0
Cichorium Intybus L.	HA	-	A	5	0	0	0
Haplopappus Baylahuen J. Remy	Ar	FP	N	45	25	45	40
Hipochoeris Glabra L.	HA	-	A	5	0	0	0
Madia Sativa Molina	HA	IC	N	5	5	0	0
Nassauvia Looseri Cabrera	HP	V	E	5	5	5	5
Pachylaena Atriplicifolia D. Don Ex Hook. Et Arn.	HP	V	N	0	0	10	0
Senecio Anthemidiphyllus J. Remy	Ar	FP	N	50	10	25	10
Sonchus Asper (L.) Hill	HA	-	A	15	0	0	0
Taraxacum Officinale Weber Ex F.H. Wigg.	HP	-	A	30	0	0	0
Tessaria Absinthioides (Hook. Et Arn.) DC.	Ar	FP	N	50	30	50	45
Werneria Pygmaea Gillies Ex Hook. Et Arn.	HP	FP	N	60	50	55	35
Brassicaceae							
Descurainia Pimpinellifolia (Barnéoud) O.E. Schulz	HA	FP	N	15	0	5	0
Hirschfeldia Incana (L.) Lagrèze-Fossat	HA	-	A	20	5	0	0
Buddlejaceae							
Buddleja Suaveolens Kunth Et Bouché	Ar	V	E	40	20	15	10
Cactaceae							
Mahueniopsis Glomerata (Haw.) R. Kiesling	Ar	V	N	25	0	20	0
Caesalpiniaceae							
Senna Urmenetae (Phil.) H.S. Irwin Et Barneby	Ar	FP	E	5	0	0	0
Calyceraceae							
Nastanthus Caespitosus (Phil.) Reiche	HP	FP	N	0	0	5	0
Chenopodiaceae							
Chenopodium Ambrosioides L.	HP	FP	N	25	0	15	5
Convolvulaceae							
Convolvulus Arvensis L.	HP	-	A	5	0	15	5
Cyperaceae							
Cyperus Rotundus L.	HP	-	A	5	0	10	0
Ephedraceae							
Ephedra Breana Phil.	Ar	FP	N	70	45	55	50
Equisetaceae							

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Equisetum Bogotense Kunth	HP	IC(VU?)	N	5	0	0	0
Fabaceae							
Adesmia Aegiceras Phil.	Ar	FP	N	0	0	5	0
Adesmia Echinus K. Presl	Ar	FP	N	0	0	5	0
Adesmia Hystrix Phil.	Ar	IC(FP?)	E	40	35	45	25
Adesmia Sp. 1	Ar	-	-	20	5	25	15
Adesmia Sp. 2	Ar	-	-	5	0	5	0
Astragalus Bustillosii Clos	HP	FP	N	0	0	5	0
Geoffroea Decorticans (Gillies Ex Hook. Et Arn) Burkart	Ab	V	N	5	0	5	5
Medicago Lupulina L.	HA	-	A	25	5	5	0
Medicago Sativa L.	HP	-	A	15	0	0	0
Geraniaceae							
Erodium Cicutarium (L.) L`Hér. Ex Aiton	HA	-	A	10	0	0	0
Geranium Core-Core Steud.	HP	IC(FP?)	N	15	10	5	0
Poaceae							
Cortaderia Rudiuscula Stapf	HP	V	N	60	55	65	35
Distichlis Sp.	HP	-	-	5	0	15	10
Festuca Sp.	HP	-	-	0	0	5	0
Jarava Chrysophylla (E. Desv.) Peñail.	HP	FP	N	80	35	65	60
Muhlenbergia Asperifolia (Nees Et Meyen Ex Trin.) Parodi	HP	FP	N	10	5	0	0
Phragmites Sp.	HP	-	-	0	0	10	0
Iridaceae							
Sisyrinchium Iridifolium Kunth	HP	FP	N	40	15	75	25
Juncaceae							
Juncus Arcticus Willd.	HP	FP	N	25	10	15	15
Labiatae							
Kurzamra Pulchella (Clos) Kuntze	HP	V	N	5	5	0	0
Mentha Piperita L.	HP	-	A	10	5	0	0
Mentha Suaveolens Ehrh.	HP	-	A	5	5	0	0
Linaceae							
Linum Macraei Benth.	HP	FP	E	10	0	0	0
Loasaceae							
Loasa Malesherbioides Phil.	HA	IC(FP?)	N	10	0	5	0
Loranthaceae							
Tristerix Verticillatus (Ruiz Et Pav.) Barlow Et Wiens	Ar	FP	N	10	0	5	0
Lythraceae							
Lythrum Hyssopifolium L.	HA	-	A	5	5	0	0
Malesherbiaceae							
Malesherbia Humilis Poepp.	HA	FP	N	5	5	0	0
Malvaceae							
Cristaria Andicola Gay	HP	FP	N	0	0	15	0
Cristaria Inconspicua F. Phil. Ex Phil.	HA	FP	N	0	0	5	5
Mimosaceae							
Acacia Caven (Molina) Molina	Ab	FP	N	20	10	20	15
Nyctaginaceae							
Boerhavia Diffusa L.	HP	FP	N	5	0	0	0
Oxalidaceae							

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Oxalis Compacta Gillies Ex Hook. Et Arn.	HP	IC(FP?)	N	5	0	0	0
Plantaginaceae							
Plantago Hispidula Ruiz Et Pav.	HA	FP	E	10	0	0	0
Plantago Lanceolata L.	HP	-	A	5	5	10	5
Plantago Pachyneura Steud.	HP	FP	N	20	10	0	0
Polygonaceae							
Polygonum Aviculare L.	HP	-	A	10	0	0	0
Rumex Longifolius DC.	HP	-	A	5	0	0	0
Portulacaceae							
Calandrinia Affinis Gillies Ex Arn.	HP	FP	N	0	0	5	0
Ranunculaceae							
Ranunculus Cimbalaria Pursh	HP	FP	N	10	5	10	0
Rhamnaceae							
Discaria Trinervis (Gillies Ex Hook. Et Arn.) Reiche	Ar	V	N	35	5	15	0
Rosaceae							
Acaena Magellanica (Lam.) Vahl	HP	FP	N	25	15	30	0
Salicaceae							
Salix Babilónica L.	Ar	-	A	0	0	15	5
Salix Humboldtiana Willd.	Ar	V	N	5	0	0	0
Saxifragaceae							
Escallonia Angustifolia K. Presl	Ar	FP	N	5	5	0	0
Scrophulariaceae							
Mimulus Depressus Phil.	HP	FP	N	0	0	5	0
Mimulus Luteus L.	HP	FP	N	5	0	0	0
Solanaceae							
Fabiana Imbricata Ruiz Et Pav.	Ar	FP	N	55	35	40	30
Lycium Minutifolium J. Remy	Ar	FP	E	5	5	5	0
Solanum Eleagnifolium Cav.	HP	-	A	0	0	5	0
Vivianiaceae							
Viviania Marifolia Cav.	Ar	FP	N	20	10	10	10

HP: Perennial herb, HA: Annual herb, Ab: Trees, Ar: Bush, FP: Safe, IC(VU?): Insufficiently known, IC(FP?): Insufficiently known, IC: Insufficiently known, V: Vulnerable, A: Allochtonous, and -: No history.
[1]Sampling summer season, (February-March 2006). [2]Sampling winter season (November-December 2006).

themidiphyllus, *Sisyrinchium iridifolium*, *Tessaria absinthioides* and *Werneria pygmaea*. The most represented families were Asteraceae (15 species), Fabaceae (9 species) and Poaceae (6 species). The most frequent forms of growth were perennial herb (41) and bush (22).

According to their biogeographical origin, the species identified were grouped into 56 native or autochthonous species, from which seven are endemic to the Region, 18 species are alochthonous or introduced. Five taxa were identified at the genus level. Seventeen species were identified with problems of conservation. The most frequent native or autochthonous species in both seasons were *C. rudiuscula* (60-65%), *E. breana* (70-55%), *F. imbricata* (55-40%), *J. chrysophylla* (80-65%), *S. anthemidiphyllus* (50-25%), *S. iridifolium* (40-75%), *T. absinthioides* (50-50%) and *W. pygmaea* (60-55%) (Squeo *et al.*, 2008).

In addition to the species with problems of conservation (Squeo *et al.,* 2008), *Alstroemeria andina* Phil., represents the North latitudinal limit for the species. Four monotypical genera (*Geoffroea, Kurzamra, Phragmites* and *Tessaria*) and five monogeneric families (Buddlejaceae, Ephedraceae, Equisetaceae, Malesherbiaceae and Oxilidaceae) were scarcely represented.

The index of biodiversity showed average values of 1.46 ± 0.47 during the summer season and 1.43 ± 0.47 in the winter season, without significant differences between seasons regarding biodiversity (Kruskal-Wallis, p = 0.7). In the summer season, the most frequently grazed species were *W. pygmaea* (50%), and in the winter they were *C. rudiuscula* (55%); *E. breana* (50%) and *J. chrysophylla* (60%) (Table 1).

The distribution of the species richness through the altitudinal gradient in the meadows and hillsides in the summer season showed a concentrated core of species close to the town Junta de Valeriano (Figure 1), which lies between 2000-2800 m above sea level (a.s.l.). Low values for the index of biodiversity were observed in both seasons around Laguna Grande (3200-3400 m a.s.l.). A higher number of grazed species were found in large meadows during the summer season (2000-2200 and 2700-3000 m a.s.l.); a higher number of grazed species were mainly associated with hillsides in the winter season (2200, 2600 and 3300 m a.s.l.). The Kruskal-Wallis test identified significant differences in the three variables (richness, index of biodiversity and number of grazed species, Figure 2) grouped in zones of summer and winter use; all of them present higher values in winter use, richness 13.00 ± 4.42 (p = 0.000), biodiversity 1.73 ± 0.30 (p = 0.010) and the number of grazed species 6.00 ± 2.59 (p = 0.047). There were not significant differences in the type of habitat.

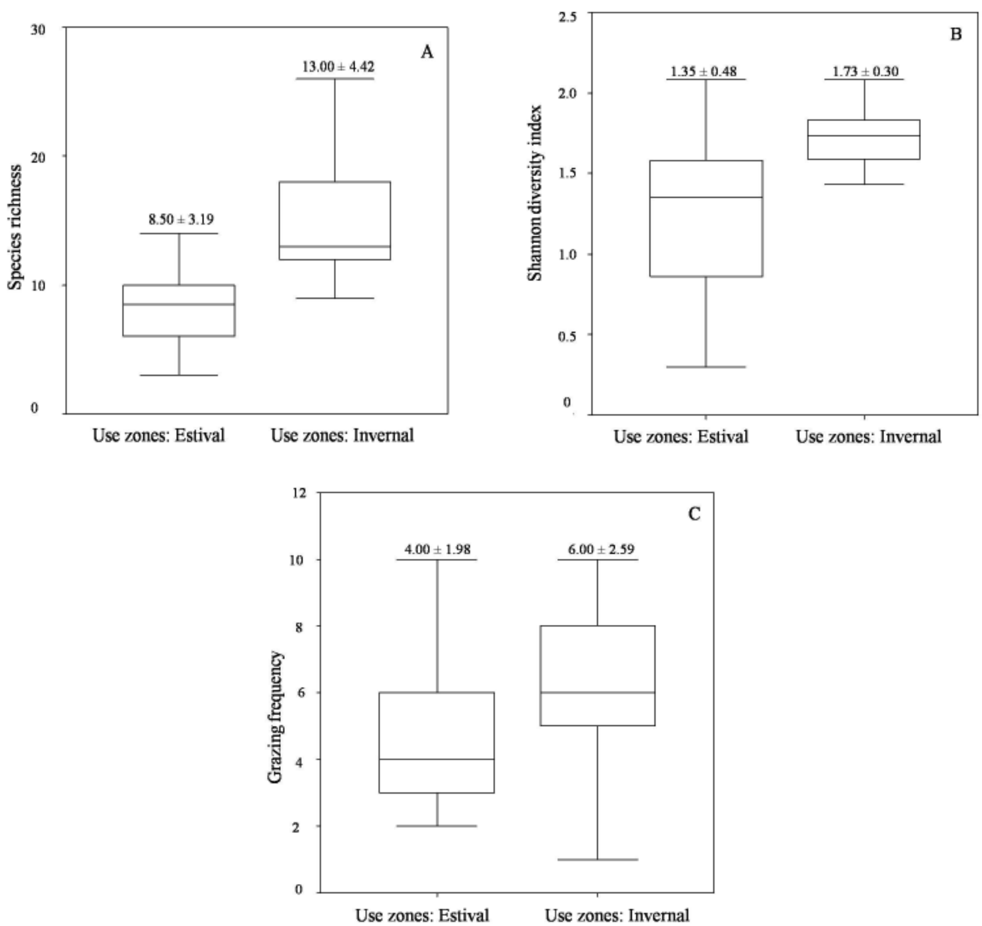

Figure 2. Box plot of (A) the species richness variable, (B) the diversity, and (C) the grazing frequency in a period of grazing use in an elevation gradient.

The relationship between the number of grazed species and the index of biodiversity is presented in Figure 3. During winter use, we confirmed that small changes in the index of biodiversity are associated with changes in the number of grazed species, which is observed in the slope of $y = 7.56x - 6.39$, $R^2 = 0.69$ (where y represents the number of grazed species, and x the index of biodiversity). A different behavior was observed during summer use, where the slope between the number of grazed species and the index of biodiversity is lower $y = 2.94x + 0.94$, $R^2 = 0.70$ (Figure 3A).

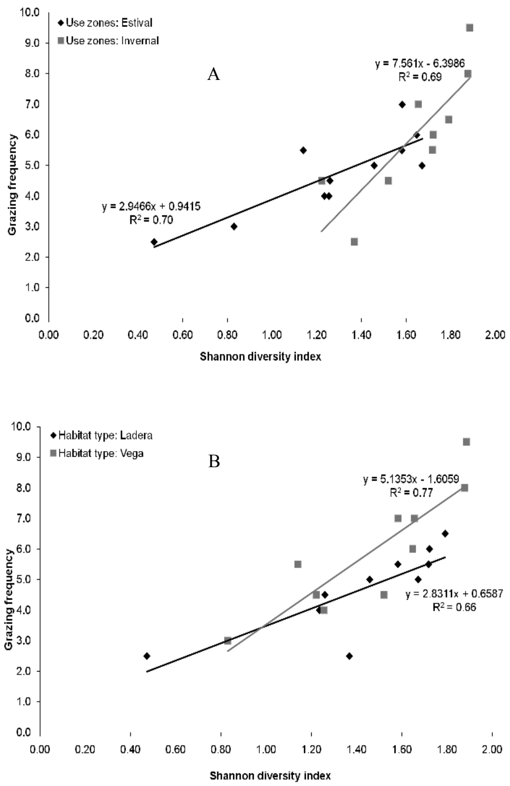

Figure 3. Relationships between the variables of Shannon diversity index and grazing frequency in (A) use zones and (B) habitat type in an elevation gradient.

The relationship between the number of grazed species and the index of biodiversity according to the type of habitat (Figure 3B) showed that small changes in the index of biodiversity in the meadows were associated with higher values of the number of grazed species ($y = 5.13x - 1.60$, $R^2 = 0.77$). In the hillside habitat, less evident changes were observed, as shown by the lower slope ($y = 2.83x + 0.65$ $R^2 = 0.66$).

Discussion

Several studies have collected information on floral richness. Cavieres *et al.* (2000) recorded 103 species in the Alpine zone of the central zone of Chile; Chabot and Billings (1972) recorded 72 species in the Alpine vegetation of Bishop Creek, California; Ferreyra *et al.* (1998) identified 136 species in the Andes Patagonia of Argentina, and Arroyo *et al.* (1984) identified 210 species in a altitudinal gradient (Junta de Valeriano, 1900 m, Laguna Grande, 3400 m). The xeric conditions characterizing the Andes in Chile and Argentina (Villagrán *et al*., 1983) explain, in part, the low richness of species and vegetation with coverage not exceeding 50%. In the present study, 79 taxa were identified, which is a lower richness value than that observed by Arroyo *et al.* (1984), who made scanning samplings every 50 m. The unequal collection efforts can explain the differences in the number of species observed.

The vascular flora of the area under study had a high value of conservation; species at their North latitudinal limit were recorded in the gradient (*Alstroemeria andina*) (Arroyo *et al*., 1984; Squeo *et al*., 2006). In addition, 66 genera were recorded in the area, four of which were monotypical of the vascular flora of Chile (*Geoffroea, Phragmites, Tessaria* and *Kurzamra*), and 40 families were recorded, five of which were monogeneric (Buddlejaceae, Ephedraceae, Equisetaceae, Malesherbiaceae and Oxalidaceae) (Marticorena and Quezada, 1985; Marticorena, 1990; Squeo *et al*., 2008).

Similar to the study carried out in the sector by Arroyo *et al.* (1984), in which 51% of perennial herbs and 23% of bushes were identified, the most frequent growth forms in the present study were found to be perennial herbs, which are more habitual in meadow zones with higher humidity (51.90%), while bush-like species (27.85%) were found to be more represented in the hillsides (Arroyo *et al.,* 1988).

Based on the biogeographical origin of the species, 70.89% of native or autochthonous species were identified, of which 8.86% were endemic and 22.78% were allochthonous or introduced. Arroyo *et al.* (1984) estimated that of the 48.57% of native species, 20.95% were endemic and 4.76% were introduced. An increase in the percentage of introduced species was observed; 12 new records were made in the zone (*Hipochoeris glabra*, *Cichorium intybus*, *Hirschfeldia incana*, *Medicago lupulina*, *Medicago sativa*, *Mentha suaveolens*, *Mentha piperita*, *Lythrum hyssopifolium*, *Plantago lanceolata*, *Rumex longifolius* and *Salix babilónica*).

Arroyo *et al.* (1984) identified 27 species with conservation problems in their 2006 study; 17 of these species were identified, and six corresponded to new records of species with conservation problems (*Baccharis tola*, *C. rudiuscula*, *G. decorticans*, *Kurzamra pulchella*, *Nassauvia looseri and Mahueniopsis glomerata*).

A slight decline in the richness of vegetal species in the winter season was observed (summer season n = 64 and winter season n = 53), possibly due to the intense drought that affected the zone in 2005 and 2006. In addition, the gradient has been strongly affected over the last few decades by intense grazing, the extraction of firewood and medicinal plants and other activities. In a naturally regulated system, we expect the vegetation and native herbivore population to be balanced so that vegetal communities in the ecosystem persist. Overgrazing can upset this balance and lead to a state of degradation, decreasing the herbaceous cover and increasing the risk of erosion (FAO 1968; Morand-Fehr and de Simiane, 1977).

Mazancourt *et al.* (2000) and Alados *et al.* (2004) showed that there is an optimal level of grazing that is feasible. This level depends on the recycling efficiency and the capacity of the plant community to recover. The "intermediate disturbance" hypothesis (Connell, 1978; Sousa, 1984; Alados *et al.*, 2004) states that intermediate levels of disturbances actually favor biodiversity, due to the increased competence of ecosystems that are rich in resources (Piggot, 1980; Alados *et al.*, 2004). In semiarid grazing ecosystems, however, irreversible changes to the vegetation occur when the number of herbivores is high, in comparison with natural auto-regulated systems (Van de Koppel *et al.*, 2000; Alados *et al.*, 2004).

The presence of domestic cattle, particularly in years of low food availability as occurred in our study sector during 2006, must be included in the analysis of the ecosystem dynamics (Squeo *et al.*, 2006). We and others have found that the species richness declines with grazing, revealing a significant effect of this activity on the species biodiversity (Nai-Bregaglio *et al.*, 2002; Alados *et al.*, 2003). In the arid and semiarid regions of western South America, low seasonal precipitations have limited productivity in most years (Oksanen, 1988). In the region of Atacama, two consecutive dry years occurred, acting in concert with other factors to cause changes in the flora and vegetation of the Region.

Insignificant differences were observed in the index of biodiversity between the two sampling seasons in the present study. Other investigators have shown that extensive livestock influences vegetation, causing a significant decrease of floral biodiversity (Van de Koppel *et al.*, 2000).

As observed in our sector, in the Andes chain in Northern Chile, (Arroyo *et al.* 1988; Villagrán *et al.*, 1983, 1982, 1981), the species richness was found to decrease by altitude, with the elevation in zones, and with winter precipitation. The distribution of total species richness throughout the altitudinal gradient showed a species concentration in sectors containing large meadows. This concentration of species, associated with a higher percentage of adventitious species, occurred in zones with high anthropic impact. *Medicago sativa* is an adventitious species that is naturalized in the zone and is present in some sectors of the gradient. Two adventitious species were identified in the areas surrounding Laguna Grande: *Cyperus rotundus* and *Taraxacum officinale*. The concentration of species, however, is associated with a higher percentage of endemic species in the sector; in this case, the altitude limits the establishment of other native or adventitious species from lower zones of the gradient (Wilson *et al.*, 1992).

The spatial distribution of the species is related to the altitudinal variation in the temperature, edaphic conditions, drainage and other factors; floral segregation between altitudinal floors is evident (Luebert and Gajardo, 2000). Higher values of richness and biodiversity index occur in the meadows, zones with more available resources, mainly water from the river courses and underground sources (Villagrán, 2006).

The summer use zone (particularly around Laguna Grande) was characterized by low indexes of biodiversity during both seasons. This area was found to be highly affected by extensive goats and the extraction of firewood and medicinal plants during the summer pastures season. A higher percentage of endemic species was also evident in this zone, one of the important characteristics of the Mediterranean Andes (Gajardo, 1992). A lower slope was observed in the relationship between the index of biodiversity and the number of grazed species in the zone of summer use, where the disturbance is not permanent. Thus, the vegetation has a period of recovery, when some species recover, others emerge and other annual species flower according to their phenology. The disturbance in the zone of winter use is permanent, however, and although there is a higher index of biodiversity, the number of grazed species is higher, as it is the adventitious species.

The grazed species were concentrated mainly in large meadows, where there is a higher availability of biomass for the cattle. In the winter season, however, a higher number of grazed species were associated with the hillsides, where cattle would have better use of vegetation. In addition, a higher slope in the relationship between the index of biodiversity and the number of grazed species in the meadow habitat was evident; higher index values of biodiversity were observed, which were related to a higher number of adventitious species, unlike what was observed in the hillsides, which have a lower availability of resources.

In other semiarid areas, two human activities, namely grazing and extraction of firewood, are known to affect the distribution of vegetation (Dube and Pickup, 2001; Dembélé *et al.,* 2006). Similar to the present study, in Malí (Nigeria) the grazing has been shown to be limited by the available resources, rivers and underground waters, favoring the formation of zones with abundant vegetation (Dube and Pickup, 2001, Dembélé *et al.,* 2006).

As for the richness and the indexes of biodiversity, the numbers of grazed species in the summer and winter use zones were significantly different across altitudinal gradients; higher values for all the three cases were obtained in the range of winter use (1900-2600 m high). These higher values for richness and index of biodiversity were associated with a higher number of adventitious species in that sector; in addition, browsing is more frequent in the winter use range, and thus it impacts the area for the whole year. Due to the climatic conditions during winter, goats only consume the vegetation up to an altitude of 2600 m. In the gradient studied, the presence of browsing was limited by climatic conditions (winter rains); the higher richness and indexes of biodiversity in the winter range was influenced by the presence of adventitious species.

As described by Meserve *et al.* (2004), long-term field studies and experimental manipulations are particularly important for understanding the interaction between biotic and abiotic factors in arid and semiarid systems because the population densities are often low and the abiotic events, such as extreme droughts, occur at long temporary scales (between two to seven years). Therefore, it is important to conduct long-term studies and experimental manipulations in the area (exclusions) to identify the biotic and abiotic effects on the flora and vegetation more clearly.

Regarding the native flora of the area under study, we found a scarce representation of species for each genus, the presence of latitudinal limits for some species, genus and monotypical families, and the concentration of endemic vegetal species in places of high anthropic use. The high frequency of browsing concentrated in places characterized by large meadows and the anthropic pressure that has been exerted on this ecosystem for decades could be changing the vegetation distribution. This ecosystem could be managed sustainably to ensure the permanence of endemic species and floral biodiversity. The data above indicate the need for the appropriate management of natural resources and the implementation of agricultural practices that are friendly with the environment.

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Resumen

D. Sanhueza, M. Miranda, M. Gómez y C. Bonacic. 2009. Relación entre biodiversidad florística e intervención antrópica en un gradiente altitudinal, de un ecosistema altoandino, "Lagunas Huascoaltinas", Región de Atacama, Chile. Cien. Inv. Agr. 36(3):411-424. Se determinó la relación entre las variables riqueza, índice de biodiversidad y frecuencia de especies ramoneadas, en un gradiente altitudinal (1900-3400 m), el cual forma parte de un ecosistema altoandino, donde ha existido un intenso uso antrópico de la vegetación. Con el objetivo de mejorar la información acerca de la flora vascular de este lugar, se muestrearon 20 sitios en dos visitas a terreno realizadas durante el año 2006. Se identificaron 79 taxa, de los cuales, el 70,89% correspondió a especies nativas, el 22,78% a introducidas y el 8,86% a endémicas (el 6,33% restante se identificó sólo a nivel genérico). Se reconoció géneros con escasa representación de especies, limites latitudinales (*A. andina*), géneros monotípicos (*Geoffroea, Kurzamra, Phragmites* y *Tessaria*), familias monogenéricas (Buddlejaceae, Ephedraceae, Equisetaceae, Malesherbiaceae y Oxalidaceae). Por otra parte, se determinó diferencias en el patrón de distribución de las especies entre los distintos períodos de uso ganadero, evidenciándose diferencias significativas para las variables riqueza ($p < 0,001$), índice de biodiversidad ($p = 0,010$) y frecuencia de especies ramoneadas ($p = 0,047$).

Palabras clave: Gradiente altitudinal, riqueza de especies, índice de biodiversidad vegetal, intervención antrópica y ecosistemas andinos de humedad.

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