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THE EFFECT OF CATTLE AND TERRESTRIAL BROMELIAD REMOVAL ON THE REGENERATION AND DIVERSITY OF A WET CHACO FOREST IN ARGENTINA

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Executive Summary

Conservation of Wet Chaco forests is of high priority. In Argentina, almost every area of this extensive biome has been altered by human activities. In the last century, these forests were logged for the tannin industry and nowadays cattle grazing and firewood extraction are the main disturbances. The understorey of these forests includes spiny-bromeliad colonies that are sometimes removed to ease cattle management. These bromeliads intercept and retain water, litter, and seeds inside their tanks and their removal may modify water and organic matter dynamics and increase cattle trampling, thus affecting forest regeneration and biodiversity.

Objective: to set up an experiment to assess the effects of cattle and bromeliads on forest regeneration and biodiversity. We consider that the objectives have been partially accomplished.

Preliminary results: With support from the RSG we obtained preliminary results at three different spatial scales [i.e. 1- among convex areas covered with terrestrial bromeliads, 2- within convex areas between sectors dominated by *Aechmea distichantha* or *Bromelia serra*, and 3- within convex areas between different habitats (understorey vs forest edge)]. At the first scale, we present a detailed description of the studied plots with regards to soil and vegetation (i.e. forest structure and species composition, canopy cover, understorey structure). At the second scale, we evaluated whether there were differences in soil physical and chemical properties in sectors dominated by *Aechmea distichantha* or by *Bromelia serra*, and whether these species were associated with mycorrhizae. At the third scale, we show environmental data for each habitat, and present results about differences in plant morphology and phytotelma characteristics between sun-grown and shade-grown plants of *Aechmea distichantha*, as well as abundance, richness, diversity, species and trophic group composition of macrofauna dwelling inside *Aechmea distichantha* plants. Part of this information was presented in different congresses, published in

a conservation journal (EcoLógica) and it was accepted as a chapter in a book about the Environmental Situation in Argentina 2005 edited by Fundación Vida Silvestre Argentina, which represents Word Wide Fund for Nature (WWF) in Argentina.

<u>Teaching and Development activities</u>: The diversity problems of the Wet Chaco region and preliminary results of the present work have been used as classroom examples for undergraduate students of Agricultural Sciences, Universidad Nacional de Rosario. We also used examples of our work in the post-graduate course of Metodología de la Investigación Científica [Scientific Research Methodology] addressed to professionals of different branches of the biological science.

<u>Education – Public Information</u>: As regards extra-curricular activities, preliminary results were exposed and discussed in a class to High School Biology teachers.

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I. WORK OBJECTIVES

Our objective was to set up an experiment to assess the immediate and short-term (3-5 years) impacts of bromeliad removal and cattle on the regeneration and diversity of the Wet Chaco forest.

Fulfillment of the objectives.

Short-term objectives:
With support of the RSG the project objectives were partially accomplished. We selected 16 sampling sites (200-m^2); each site consisted of a grid with 100 subplots (4m^2), where each subplot was identified with an aluminum tag. We sampled 9 plots in order to get detailed information (plants >1 mm diameter at breast height) of the woody plant community, as well as the sapling and seedling community. As we had proposed, before fencing and removing the understorey, the sites were characterized for several topsoil variables (pH, phosphorus, organic matter, soil moisture content, bulk density), and canopy cover (subjective scale). As the plots showed high heterogeneity, and bromeliad species distribution seemed to be associated to it, we sampled the same topsoil variables in patches dominated by either *Aechmea distichantha* or *Bromelia serra*. In all 16 plots we placed pitfall traps to assess the diversity of soil-dwelling arthropods, and samples are being analyzed. In summer, all animals living inside the tank of *Aechmea distichantha* plants growing in the sun and in the shade were removed, and we estimated their diversity and abundance. Fencing and understorey removal has been postponed due to climatic problems (*See* IV Difficulties).

Long-term plans proposed in the July 2004 application to RSG are being achieved satisfactorily. As regards ***Teaching***, this year I actively participated in two courses (Ecology and Biogeography) for Agronomy students (undergraduate courses), as well as in a Scientific Research Methodology course (graduate course) (III.3). As regards ***Research*** and my professional formation, I participated in other research projects, I acted as member of a MSc Committee, and I was asked to referee scientific papers for two international journals (III.1). Finally, as regards ***Formation of Human Resources***, I was the director of an undergraduate student (Bachelor in Biodiversity, Universidad Nacional del Litoral) (III.4). Information and field experience acquired is thus transmitted to students at Facultad de Ciencias Agrarias, Universidad Nacional de Rosario, as well as from other Universities.

II. PARTICIPANTS

PARTICIPANTS	PROJECT INVOLVEMENT	INSTITUTION
Dr. Ignacio Barberis	**Leader**	Doctoral Fellow, CONICET Auxiliary Professor Plant Ecology, UNR
Dr. Juan Pablo Lewis	**Team member**	Researcher, CONICET Professor in charge of Plant Ecology, UNR
Dr Nélida Carnevale	**Team member**	Researcher, CIUNR, Professor in Plant Ecology, UNR
Dr William Batista	**Team member**	Professor in Plant Ecology, UBA
Ing. Agr. Guillermo Montero	**Team member**	Professor in Zoology, UNR
Med. Vet. Marcelo Romano	**Team member**	Centro de Investigaciones en Biodiversidad y Ambiente (ECOSUR - non-governmental organisation)

III. ACTIVITIES DEVELOPED

III.1. RESEARCH ACTIVITIES

Publications related to the research project

Barberis I.M. and J.P. Lewis. 2005. Heterogeneity of terrestrial bromeliad colonies and regeneration of *Acacia praecox* (Fabaceae) in a humid-subtropical-Chaco forest, Argentina. *Revista de Biología Tropical* 53(3-4): 377-385.

Cavallero, L. and **I.M. Barberis**. 2005. El caraguatá: un habitante del sotobosque del quebrachal. [The caraguatá: an inhabitant of the *Schinopsis balansae* forest]. *EcoLógica* 8(2): 6-9. (See: www.ecologicaonline.com.ar)

Alzugaray C., **I. Barberis, N. Carnevale**, N. Di Leo, **J.P. Lewis** and D. López. (in press). Estado actual de las comunidades vegetales de la Cuña Boscosa de Santa Fe. [Present conservation status of plant communities of the Cuña Boscosa of Santa Fe]. In: Brown A.D. and Corcuera J. (Eds.). Situación Ambiental Argentina 2005. Editorial Fundación Vida Silvestre Argentina, Buenos Aires. [Fundación Vida Silvestre Argentina represents World Wide Fund for Nature (WWF) in Argentina]

Barberis I.M., **J.P. Lewis** and **W.B. Batista**. 2005. Heterogeneidad estructural de los bosques de la Cuña Boscosa de Santa Fe en distintas escalas espaciales. [Structural heterogeneity of the forests of the Santa Fe Forest Wedge at different spatial scales]. In: Oesterheld M., Aguiar M., Ghersa C. and Paruelo J. (Eds.). La heterogeneidad de la vegetación de los agroecosistemas. Un homenaje a Rolando León. Pp. 47-62. Editorial: Facultad de Agronomía, UBA.

Publications on other subjects of ecology and conservation

Barberis I.M. and E.V.J. Tanner. 2005. Gaps and root trenching increase tree seedling growth in Panamanian semi-evergreen forest. *Ecology* 86(3): 667-674.

Romano M., I. Barberis, F. Pagano and J. Maidagan. 2005. Seasonal and interannual variation in waterbird abundance and species composition in the Melincué saline lake, Argentina. *European Journal of Wildlife Research* 51: 1-13.

Lewis J.P., D.E. Prado and **I.M. Barberis**. (in press). Los remanentes de bosques del Espinal en la provincia de Córdoba. [Remnants of the Espinal forests in Córdoba province]. In: Brown A.D. and Corcuera J. (Eds.). Situación Ambiental Argentina 2005. Editorial Fundación Vida Silvestre Argentina, Buenos Aires. [Fundación Vida Silvestre Argentina represents World Wide Fund for Nature (WWF) in Argentina].

Romano M., F. Pagano, **I. Barberis** and J. Maidagan. 2005. Registros del gaviotín pico negro (*Sterna nilotica*) y playerito unicolor (*Calidris bairdii*) en el sur de la provincia de Santa Fe, Argentina. [Records of the gull-billed tern (*Sterna nilotica*) and the Bairds's sandpiper (*Calidris bairdii*) at the south of the Santa Fe province]. *Revista Nuestras Aves* 49: 29.

Trossero M., P. Griffa, S. González, E. Coronati and **I. Barberis**. 2005. Emergencia, supervivencia y establecimiento de plántulas de *Gleditsia triacanthos* y *Bauhinia forficata* en claros y sotobosques del Parque Villarino, Zavalla, Santa Fe, Argentina. [Emergence, survival and establishment of *Gleditsia triacanthos* and *Bauhinia forficata* seedlings in gaps and understoreys in Parque Villarino, Zavalla, province of Santa Fe, Argentina]. *Revista de Investigaciones de la Facultad de Ciencias Agrarias –Universidad Nacional de Rosario* 7: 51-61.

Congress communications

Pire E.F., **I.M. Barberis**, J.L. Vesprini and **J.P. Lewis**. Fenología foliar de especies leñosas de un quebrachal de la Cuña Boscosa Santafesina. [Foliar phenology of woody species of a quebrachal forest in the Cuña Boscosa Santafesina]. VI Congreso-XXIV Reunión Anual de la Sociedad de Biología de Rosario. Rosario, 1-2 December 2004.

Romano M., F. Pagano, **I. Barberis** and J. Maidagan. Distribución de aves acuáticas en diferentes ambientes del humedal Laguna Melincué. [Waterfowl distribution in different habitats of the Laguna Melincué wetland]. VI Congreso-XXIV Reunión Anual de la Sociedad de Biología de Rosario. Rosario, 1-2 December 2004.

Romano M., I. Barberis, F. Pagano and J. Maidagan. Variaciones estacionales e interanuales en la abundancia y composición de aves acuáticas en la laguna Melincué, Argentina. [Seasonal and interannual variations in the abundance and species composition of waterfowl in laguna Melincué, Argentina]. Simposio de Humedales Altoandinos. Salta, 13-17 February 2005.

Montero, G., C. Feruglio and **I. Barberis**. Abundancia, riqueza y diversidad de macrofauna en plantas de *Aechmea distichantha* ubicadas al sol y a la sombra en un quebrachal del Chaco santafesino. [Macrofauna abundance, richness and diversity in *Aechmea distichantha* plants growing in sun and shade conditions in a quebrachal of the Chaco santafesino]. VI Congreso Argentino de Entomología. San Miguel de Tucumán, 12-15 September 2005.

Barberis, I.M. and **M. Romano**. Diez años de censos de aves en Melincué. [Ten years of waterfowl censuses in Meincué]. III Jornadas Conmemoración del Día del Medioambiente. Organizado por Escuela de Agrimensura, Inst. de Fisiografía y Geología "Dr. Alfredo Castellanos", Laboratorio de Energía Alternativa, FCEIA – IFIR, Sec. de Extensión Universitaria de la Facultad de Ciencias Exactas, Ingeniería y Agrimensura-UNR, Centro de Investigaciones en Biodiversidad y Ambiente ECOSUR, Inst. Sup. del Profesorado Nº 16, "Dr. Bernardo Houssay". Facultad de Ingeniería, Universidad Nacional de Rosario, 7 June 2005.

Alzugaray, C., **N.J. Carnevale**, N. Di Leo and D. López. Mapa de clasificación de unidades de cobertura de vegetación de la Cuña Boscosa Santafesina. [Classification map of vegetation unit from the Cuña Boscosa Santafesina]. Tercer Congreso Nacional sobre Manejo de Pastizales Naturales. Paraná, Entre Ríos, 12-14 October 2005.

Barberis, I.M., D.E. Prado and **J.P. Lewis**. El Espinal Periestépico: ¿Desaparición, permanencia o transformación de una unidad fitogeográfica?. [The Espinal Periestépico: disappearance, permanence or transformation of a phytogeographical unit?] XXX Jornadas Argentinas de Botánica. Rosario, 6-10 November 2005. Boletín de la Sociedad Argentina de Botánica 10(Suplemento):17. ISSN 0373-580X.

Feldman S.R., M. Cabello, A. Patrignani and **I. Barberis**. Presencia de micorrizas arbusculares asociadas a bromeliáceas del quebrachal de *Schinopsis balansae* en la Cuña Boscosa de Santa Fe. [Mycorrhizae associated to Bromeliaceae species from the understory of a Santafesinian Chaco forest]. XXX Jornadas Argentinas de Botánica. Rosario, 6-10 November 2005. Boletín de la Sociedad Argentina de Botánica 10(Suplemento):159. ISSN 0373-580X.

Cavallero, L, **I.M. Barberis** and D. López. Diferencias en la morfología de plantas de *Aechmea distichantha* Lem. crecidas al sol y a la sombra. [Morphological differences in *Aechmea distichantha* plants grown in the sun and in the shade]. XXX Jornadas Argentinas de Botánica. Rosario, 6-10 November 2005. Boletín de la Sociedad Argentina de Botánica 10(Suplemento):172. ISSN 0373-580X.

Participation in research projects

Barberis I. and **Carnevale, N.J.** Researchers of the project: "Estudios ecológicos sobre flora y vegetación en ecosistemas chaco-pampeanos". [Ecological studies of flora and vegetation from

Chaco-Pampean ecosystems]. Project AGR21. Universidad Nacional de Rosario. *Director: **Lewis J.P.*** 2004-2006.

Barberis I. Director of the project: “Efecto de las bromeliáceas terrestres en la dinámica del agua del sotobosque de un quebrachal de la Cuña Boscosa Santafesina”. [Effect of terrestrial bromeliads on the water dynamics of the quebrachal understorey in the Cuña Boscosa Santafesina]. Foncyt BID 1201/OC-AR-PICT N°01-12686.

Lewis J.P. Director of the project: “Desarrollo de la biodiversidad en ecosistemas transicionales Chaco-Pampeanos”. [Biodiversity development in transicional ecosystems from Chaco and Pampas]. CONICET PIP 6501.

Participation in Academic Committies

Barberis, I.M.- Member of the Magister Scientiae in Natural Resources Committee, Facultad de Ciencias Agrarias, Universidad Nacional de Rosario (Miembro Titular de la Comisión Asesora de la Maestría en Recursos Naturales de la Facultad de Ciencias Agrarias, U.N.R.). December 2003 – December 2005. Resolución C.D. N° 333/03.

Lewis, J.P. Member of Comisión de Biología [Biology Committee] of CONICET (Consejo Nacional de Investigaciones Científicas y Tecnológicas).

Referee for International Journals:

- European Journal of Wildlife Research.
- Plant Ecology.

III.2. SCIENTIFIC MEMBERSHIPS

- British Ecological Society.
- Asociación Argentina de Ecología.
- Aves Argentinas (Asociación Ornitológica del Plata)
- Sociedad de Biología de Rosario.

III.3. TEACHING AND DEVELOPMENT EXPERIENCE

Barberis I. Teacher of the post-graduate course “Metodología de la Investigación Científica”. [Scientific Research Methodology]. July 31-August 2, 2005. Facultad de Ciencias Agrarias, Universidad Nacional de Rosario. Teaching team: Dr **Ignacio Barberis**, Dr Javier Vitta.

Barberis I. Teaching Assistant of the ‘Ecología Vegetal’ undergraduate course [Plant Ecology], Facultad de Ciencias Agrarias, Universidad Nacional de Rosario. August-December 2005.

Barberis I. Teaching Assistant of the ‘Biogeografía’ undergraduate course [Biogeography], Facultad de Ciencias Agrarias, Universidad Nacional de Rosario. March-June 2005.

Barberis I. Tutor for a group of undergraduate students in Taller I ‘La investigación en las ciencias naturales y sociales’. [Research in Natural and Social Sciences], Facultad de Ciencias Agrarias, Universidad Nacional de Rosario. March-December 2005.

Barberis I. Teaching Assistant of the III Module for High School teachers in Biology, organized by Facultad de Ciencias Bioquímicas y Farmacéuticas, Universidad Nacional de Rosario. 15 October 2005.

Lewis J.P. Director of the Ecología Vegetal undergraduate course [Plant Ecology], Facultad de Ciencias Agrarias, Universidad Nacional de Rosario. August-December 2005.

Lewis J.P. Teacher of the post-graduate course "Biogeografía". [Biogeography]. November 14-18, 2005. Facultad de Ciencias Agrarias, Universidad Nacional de Rosario. Teaching team: Dr Darién Prado, Dr **Juan Pablo Lewis**.

III.4. FORMATION OF HUMAN RESOURCES

Barberis I. Supervisor of an undergraduate thesis to get the degree of Bachelor in Biodiversity (Licenciatura en Biodiversidad). Facultad de Humanidades y Ciencias, Universidad Nacional del Litoral. Student: Laura Cavallero. Subject: 'Variaciones morfológicas de *Aechmea distichantha* Lem. (Bromeliaceae, Bromelioideae) al sol y a la sombra y su relación con la captación, acumulación y pérdida de agua'. [Morphological variation of *Aechmea distichantha* Lem. (Bromeliaceae, Bromelioideae) plants growing in the sun and in the shade and its relationship with water capture, accumulation and loss]. *Viva*: October 7, 2005.

Lewis J.P. Active participation in the formation of human resources at Facultad de Ciencias Agrarias, Universidad Nacional de Rosario, Argentina, as Supervisor of 2 doctoral thesis (in progress) and 1 MSc thesis (Student: Silvia Boccanelli. Subject: 'Desarrollo de la sucesión secundaria luego del abandono de campos agrícolas en el sur de la provincia de Santa Fe (Argentina)'. [Old-field secondary succession in the south of the Santa Fe province (Argentina)]. *Viva*: June 3, 2005).

Carnevale N.J. Co-Supervisor of one MSc thesis (Student: Claudia Alzugaray. Subject: Ecofisiología de semillas y plantas jóvenes de *Schinopsis balansae* Engl. (quebracho colorado) y *Aspidosperma quebracho-blanco* Schlecth. (quebracho blanco). *Viva*: August 2005). Facultad de Ciencias Agrarias, Universidad Nacional de Rosario.

IV. DIFFICULTIES

In the Wet Chaco, the dry season normally occurs in winter (June-September). However, This year the beginning of the wet period has been delayed for several months. Consequently, the spring/summer survey of soil-dwelling arthropods was also delayed and also made difficult to identify the plant species in our plots. As we proposed to finish characterizing the sites before allocating the plots to each treatment combination (i.e. bromeliad removal and fencing), I regret to say that still one year after receiving the RSG we are not yet able to allocate the plots to the proposed treatments. We hope to finish our survey in the austral Summer 2006, and therefore allocating the plots to each treatment combination as soon as possible.

In our proposal we applied for a device to measure volumetric soil water content (ThetaKit v3from Delta T Devices, Cambridge, UK). The cost of this device was much more expensive that in our proposal because of two factors: modification of the exchange rate between GB Pound and Argentinean Pesos and inflation. Also, the custom application was done by the end of December 2004, however the device was hold in the Argentinean Customs for a long time, and finally arrived to our hands by the end of August 2005. Due to this delay, we had to measure gravimetric soil water content, which is more time-consuming and thus fewer samples could be taken.

Unfortunately, we were not able to do a much better description of our plots because the statistical package that we used to analyse multivariate data cannot handle complex experimental designs such as our experiment or the use of covariates. In order to get all the potential results from our experiment we would need to use a more powerful package such as CANOCO that includes hierarchical analysis of community variation and principal response curves method.

The money provided by RSG should be enough for setting up the experiment, but we are applying to an additional grant (RSG Continuation) in order to continue the surveys for the diversity studies.

V. MAIN PRODUCTS

V.1. PRELIMINARY TECHNICAL REPORT

INTRODUCTION

The southernmost portion of the Eastern Chaco is the Santa Fe Forest Wedge (Cuña Boscosa Santafesina), which is covered by different forest types arranged along environmental gradients correlated with the elevation gradient, and treeless areas with grasslands or wetlands (Lewis and Pire 1981). At the top of the elevation gradient are the mixed dense forests or Austro-Brazilian Transitional forests, then the *Schinopsis balansae* forests (quebrachales), which are the most widespread and characteristic forest type of the area, and at the bottom, next to wetlands, *Prosopis nigra* var. *ragonesei* woodlands (algarrobales) or *Copernicia alba* palm groves (Lewis 1991).

Through the first half of the XX century, woody communities were intensively exploited, mainly for the tannin extraction (Bitlloch and Sormani 1997). The quebrachales and algarrobales were later on used for cattle ranching and wood extraction for charcoal or firewood. In the quebrachales, like in other Chaco forests, selective logging and cattle grazing have favoured shrub encroachment (Bertonatti and Corcuera 2000). By the year 2000, woody communities covered almost 75% of the Cuña Boscosa Santafesina, whereas herbaceous communities covered a little more than 20%, and bare soil with salt in only 5% of the area (Alzugaray et al. *accepted*). Within woody communities, the quebrachales covered more than half of the area followed by algarrobales and chañarales, and finally mixed dense forests and palm groves (Alzugaray et al. *accepted*; Alzugaray et al. 2005).

Even though the area covered by natural communities in the Cuña Boscosa is still high, it is worth pointing out that, like in other Chaco areas, there are large extensions of forests and woodlands with different degrees of degradation (sometimes seriously damaged). In these degraded areas, natural vegetation was not completely replaced by crops or pastures, but they show severe structural and functional alterations (Adámoli et al. 2004). In general, the conservation status of the woody communities decreases toward the south of the Cuña Boscosa (Alzugaray et al. 2005), where we are carrying out our experiment.

In the *Schinopsis balansae* forests of the Southern Humid Chaco, woody species distribution is related to local environmental heterogeneity (Barberis et al. 2005). Density of woody individuals is higher on convex patches. These patches are dominated by tree (*Acacia praecox* and *Achatocarpus praecox*) and shrub (*Celtis pallida*, *Capparis retusa* and *Grabowskia duplicata*) species, whereas plain patches are dominated only by tree species (*Schinopsis balansae*, *Prosopis* spp. and *Geoffroea decorticans*). In dry patches all woody species are present, whereas in wet patches only a fraction of them are present. Within convex patches, trees occur in places covered by terrestrial bromeliad colonies (*Aechmea distichantha* and *Bromelia serra*) while shrubs dominate patches without them. Forest structure is controlled by heterogeneity related to microrelief and soil moisture (Barberis et al. 2002).

The convex patches with bromeliads (Eb) show a high internal heterogeneity (Barberis and Lewis 2005). In these patches, there are areas dominated by *Aechmea distichantha*, areas dominated by *Bromelia serra*, areas codominated by both species, and areas without bromeliads. Bromeliads are classified in five ecological types, based on their root system, shoot architecture, foliar trichomes, photosynthetic syndromes, habit and taxonomic distribution (Benzing 2000). *Bromelia serra* may be classified as Type II (i.e. terrestrial, with absorptive soil roots, weakly developed phytotelma, absorptive trichomes on leaf bases, and CAM photosynthetic syndrome). *Aechmea distichantha* may be classified as Type III (i.e. terrestrial or epiphytes species, with mechanical or conditional absorptive roots, with a well-developed phytotelma, absorptive trichomes on leaf bases, and most of them with CAM photosynthetic syndrome).

It has been suggested that in the Chaquenian forests the bromeliad colonies affect woody species regeneration by intercepting water and seeds, diminishing light, and reducing the physical space for seedling establishment (Bordón 1978, Martínez Crovetto 1980, Pire and Prado 2000). Thus, several authors recommend eliminating these bromeliad colonies to achieve forest regeneration (Martínez Crovetto 1980, Pire and Prado 2000). Nevertheless, these colonies may act as a mechanical barrier to cattle movement (Bordón 1978) reducing, as a consequence, trampling and grazing incidence (Pire and Prado 2000). Moreover, little is known about several potential risks of colony removal and their interactions with cattle. Besides, some bromeliad species (e.g. *Aechmea distichantha*) can hold rainwater, organic matter, as well as propagules inside the tank formed by the bases of their leaves (Benzing 2000). Therefore, areas covered by these bromeliads may have higher amount of litter and food, higher moisture, lower radiation, and lower temperature variation. These environmental characteristics would favour the development of numerous animals (e.g. arthropods, amphibians) dwelling both inside and between bromeliad plants. Therefore, the impact of colony removal and its interaction with cattle on forest regeneration and biodiversity need to be evaluated. We hypothethised that for biodiversity conservation and sustainable management it would be useful to keep some areas of the *Schinopsis balansae* forests covered with bromeliad understorey.

The object of our work was to set up an experiment to assess the immediate and short-term (3-5 years) impacts of bromeliad removal and cattle on regeneration and biodiversity of the Wet Chaco forest. Thus, in this report we show preliminary results at three different spatial scales [i.e. 1- among convex areas covered with terrestrial bromeliads, 2- within convex areas between sectors dominated by *Aechmea distichantha* or *Bromelia serra*, and 3- within convex areas between different habitats (understorey vs forest edge)]. At the first scale, we present a detailed description of the studied plots with regards to soil and vegetation (i.e. forest structure and species composition, canopy cover, understorey structure). At the second scale, we evaluated whether there were differences in physical and chemical soil properties in sectors dominated by *Aechmea distichantha* or by *Bromelia serra*, and whether these species were associated with mycorrhizae. At the third scale, we show environmental data for each habitat, and present results about differences in plant morphology and phytotelma characteristics between sun- vs. shade-grown plants of *Aechmea distichantha*, as well as abundance, richness, diversity and species composition of macrofauna dwelling inside *Aechmea distichantha* plants.

MATERIAL AND METHODS

The study is being carried out in a 400-ha stand of the *Schinopsis balansae* forest type (Lewis 1991, Lewis et al. 1997) located at Las Gamas, Santa Fe, Argentina (Estación Experimental Tito Livio Coppa, 29°28'S, 60°28'W, 58 m a.s.l.). Climate is humid temperate to warm, with mean annual temperature of about 20°C, and mean annual precipitation of about 1000 mm. Rainfall is concentrated in the summertime (December – March) and a drought of variable length occurs in winter. The forest is located on a mosaic of soils with low hydraulic conductivity and high sodium content (Espino et al. 1983). In these forests, most woody species are deciduous, with small leaves and frequently with spiny structures (Lewis et al. 1997), and the ground surface has a noticeable microrelief (Barberis et al. 1998). The vegetation structure and its floristic composition change markedly in tenths of meters in relation to differences in microtopography and soil moisture. Within convex areas of the quebrachal, the vegetation heterogeneity is related to the presence of colonies from two prickly bromeliads: *Bromelia serra* and *Aechmea distichantha* (Barberis and Lewis 2005). Both species inhabit forest understorey, but they are frequently found in forest edges where they show a different phenotype (Cavallero 2005, Cavallero and Barberis 2005).
We selected a 70-ha paddock covered by *Schinopsis balansae* forests, where we chose 16 convex areas covered with terrestrial bromeliads. Within each convex area we set up a 20 × 20-m plot. Each plot consisted of a grid with 100 subplots (4m^2 each), where each subplot was identified with an aluminum tag.

1- Convex areas covered by bromeliad understory

<u>*Forest structure and species composition*</u>

In nine plots we identified all tree species and measured their diameter at breast height (dbh), and diameter of every stem > 1 cm at 20 cm height for shrubs and trees whose stems did not reach breast height. For each plot, we calculated species richness, density (individuals 400 m^{-2}), basal area (cm^2 400 m^{-2}).
We also counted large saplings (i.e. 1 cm dbh > Individuals > 1 m tall), small saplings (1 m tall > individuals > 0.3 m tall), and seedlings (< 0.3 m tall), including individuals originating both from seed and adult plant sprouts. Large and small saplings, as well as seedlings, were identified and recorded by subplot to estimate plot density and species richness.
For each size class, we estimated individual density, species richness and beta diversity (Whittaker 1967). Species composition among size classes was compared using Multiresponse Permutation Procedure (MRPP; McCune and Mefford 1999). In the tests, each plot corresponded to a multivariate observation containing the densities of each species, and the size classes were compared.
We classified plots according to adult and seedling floristic composition using Farthest Neighbour as the linkage method and Sörensen as the distance measure. Classifications were done using PC-ORD (McCune and Mefford 1999). We tested association between adult and seedling species matrix composition using the Mantel test (McCune and Mefford 1999).

Forest canopy

For each subplot we estimated its canopy cover using a subjective scale (range: 1 = open canopy to 5 = completely covered), and we recorded the woody species present above each subplot. The same person (I.M. Barberis) estimated this index for all subplots.

Forest understorey structure

For each subplot we estimated the percentage of soil covered by terrestrial bromeliads. We also distinguished between bromeliad species (i.e. *Aechmea distichantha* and *Bromelia serra*). In three plots, we recorded the number of individuals (ramets) of each bromeliad species present in each subplot.
We used Pearson correlation to assess whether the abundances of both bromeliad species were associated. We analysed the association between the percentage of bromeliad cover with the forest canopy index, for both bromeliad species and for each one alone. We also analysed the association between bromeliad cover and canopy index with seedling species richness.

Top Soil

In each plot, we randomly selected 12 subplots, where we took a soil sample (17 mm diametre and 10 cm depth). For each plot, we made a composite sample (12 subsamples) for chemical analyses. Also, in four randomly selected subplots we took a soil sample for soil moisture content (gravimetric method), and another to estimate bulk density. The latter was obtained through the cylinder method using a gauge (6 cm diametre and 5 cm depth). Soil samples were air-dried and sieved through a 2 mm sieve. We obtained pH, organic matter (Walkley & Black method), extractable phosphorus (Bray and Kuntz I), and conductivity (conductimetric method; soil:water ratio = 1:2.5). As we only have a composite sample per plot, we graphed the data to see whether there were differences among plots for pH, organic matter, phosphorus, and conductivity. We used an Anova to analyse differences in bulk density among plots. For soil moisture, we used a Kruskall-Wallis test because variances among plots were not homogeneous.

Soil-dwelling arthropods

In August 2005 we randomly placed 5 pitfall traps in each plot. Traps were filled with acetic acid (10%) and formaldehid (2%). One week later, traps were removed, arthropods were collected, and kept in alcohol 70%. Nowadays they are being separated, identified and classified.

2- Convex sectors dominated by *Aechmea distichantha* or *Bromelia serra*

Soil analyses and mycorrhizae

In each of the 16 convex patches with bromeliad understorey we selected four sectors dominated by *Aechmea distichantha* and four dominated by *Bromelia serra*. From each sector, we took 3 samples from the top 10-cm of soil. For each patch, we mixed the samples and made a composite sample (12 subsamples) for each species. We used these composite samples for the chemical analyses (i.e. pH, organic matter, phosphorus, and conductivity). Also, from each sector, we took a soil sample for soil moisture content, and another to estimate bulk density.
The effect of bromeliad species (i.e. *Aechmea distichantha* vs *Bromelia serra*) on soil chemical variables was analysed with a Student paired t-test (Quinn and Keough 2002). We used a completely randomized block design and MIXED procedure from SAS 8.0 (SAS Institute 1999) to analyse the effect of bromeliad species on soil moisture and bulk density.

We evaluated the presence of spores and hyphae of mycorrhizal fungi in the rhizosphere and roots of *Aechmea distichantha* and *Bromelia serra.* The spores were separated by sieving and centrifugation in a saccharose gradient, and roots were stained with trypan blue. Spores and roots were mounted on slides in polyvinyl alcohol.

3- Edge or understorey of convex areas covered with bromeliads

Environmental variables

We recorded air temperature (°C), relative humidity (%), and maximum wind speed (km h^{-1}) at ten sites in summer (27 and 28 Jan. 2005). Measurements were done with GEOS 9 (Skywatch, Switzerland). Travels between sites were done from 1100 h. to 1500 h. Within each site, we distinguished three habitats (understorey, forest edge, and open areas) and the measuring order was randomly selected. We spent 30 minutes at each habitat to allow measurement stabilization. We used the Kruskall-Wallis test to analyse whether there were differences in environmental variables among habitats.

Arthropod community within tanks of Aechmea distichants *plants*

In a *Schinopsis balansae* forest close to Las Gamas, we selected 8 medium to large *Aechmea distichantha* plants from the understorey (thereafter shade plants) and 8 similar plants from the forest edge (thereafter sun plants). In the field, for each plant we measured the height from the soil to the top leaf (Scarano et al. 2002), the longer diametre and its transversal. We measured pH and temperature of the water inside the tank. In order to estimate actual water content, plants were carefully dislodged from the soil, and the inside water was poured into buckets, measured with measuring tubes, and kept in plastic bags. Later on, each plant was washed to remove all fauna inside their leaf bases. Plant blades, sheaths and stems were oven-dried at 70 ºC until constant weight and weighed with a precision scale (SCALTEC SBA 32, d=0.01 g).
Macrofauna was sieved, separated and conserved in alcohol (70%) until its identification to 'morphospecies'. For each morphospecies we determined its growth stage (i.e. larvae, nymphae or adult). Morphospecies were classified in trophic groups (i.e. detritivore, herbivore, parasite, predator, and unknown).
Plant characteristics and macrofauna abundance were analysed with generalized lineal models and species composition with multivariate methods (MRPP), using PC-ORD (McCune and Mefford 1999). For each habitat we estimated species richness, diversity (Shannon-Weaver index) and beta diversity (Whittaker 1967). We also compared species richness by rarefaction curves. This statistical method allows an estimate of the expected species richness from randomized sub-samples of individuals in a collection or census (Gotelli and Graves 1996). Curves were built by calculating mean species richness value from random samples of increasing abundance, with 1000 iterations for each abundance level, using the EcoSim program (Gotelli and Entsminger 2002).

RESULTS

1- Convex areas covered by bromeliad understory

Forest structure and species composition

In the sampled plots, we recorded 912 individuals > 1-cm dbh (Table 1) (average = 101.3 ± 10.28 woody individuals > 1-cm dbh/400 m^2; range 63-53 woody individuals > 1-cm dbh/400 m^2). We recorded 20 species; the most common were *Myrcianthes cisplatensis*, followed by *Acacia praecox* and *Achatocarpus praecox*. Most individuals were smaller than 5-cm dbh (645 individuals), while 179 individuals belonged to the 5-10 cm dbh, 72 individuals to the 10-20 cm dbh, and finally only 16 individuals were larger than 20-cm dbh. The latter belonged to only four species (*Sideroxylon obtusifolium*, *Myrcianthes cisplatensis*, *Prosopis* spp. and *Schinopsis balansae*). Basal area of the nine sampled plots averaged 1.24 m^2/400 m^2 (± 0.04 m^2/400 m^2) and ranged from 0.97 to 1.41 m^2/400 m^2.

Three species were recorded in all plots (*Acacia praecox*, *Myrcianthes cisplatensis* and *Achatocarpus praecox*), two species in 8 plots (*Sideroxylon obtusifolium* and *Coccoloba argentinensis*), and three species in 7 plots (*Celtis pallida, Schinopsis balansae*, and *Ziziphus mistol*), whereas two species (*Banara umbraticola* and *Caesalpinia paraguariensis*) were recorded in just one plot.

We recorded 324 large saplings (i.e. individuals taller than 100 cm, but thinner than 1 cm dbh) belonging to 19 species in 230 subplots (Table 1). The most widespread species were *Myrcianthes cisplatensis* and *Acacia praecox* followed by *Celtis pallida*. We also recorded 859 small saplings (i.e. individuals between 30 and 100 cm tall) belonging to 21 species in 555 subplots (Table 1). The most widespread species were *Myrcianthes cisplatensis* and *Acacia praecox*, followed by *Capparis retusa*.

We recorded 1242 seedlings (i.e. individuals < 30 cm tall) belonging to 19 species in 696 subplots (Table 1). The most widespread species were *Myrcianthes cisplatensis* and *Acacia praecox*, followed by *Sideroxylon obtusifolium* and *Aspidosperma quebracho-blanco*.

Species richness was similar among size classes, and so was their beta diversity (Table 1). For all size classes the two more abundant species were *Myrcianthes cisplatensis* and *Acacia praecox*. However, there were significant differences in species composition among size classes (MRPP: A = 0.154, P<0.00001). In the adult class there were more individuals of *Achatocarpus praecox* than in the other size classes, whereas in the seedling class there were more *Aspidosperma quebracho-blanco* than in the other size classes. Large and small sapling classes had more individuals of *Coccoloba argentinensis*, *Capparis retusa*, *Erythroxyllum microphyllum*, *Schinus fasciculata* and *Aloysia gratissim* than adult or seedling classes.

In the study plots, the species composition for adult and seedling classes was not associated (Mantel test: r = 0.155, P = 0.408). This same pattern emerged when plot dendrograms for both size classes were compared (Fig. 1).

Forest canopy

Forest canopy do not covered the whole area of the selected plots (average ± s.e.m. = 3.23 ± 0.103; scale 1=completely open to 5=completely covered). Most subplots were classes 3 and 4, and only few were completely covered or uncovered (Fig. 2).

The species with higher constancy in the canopy (i.e. present in all plots) were *Acacia praecox*, *Celtis pallida*, *Myrcianthes cisplatensis*, *Schinopsis balansae*, and *Achatocarpus praecox*, followed by *Sideroxylon obtusifolium*, *Coccoloba argentinensis*, and *Ziziphus mistol*. The most frequent species were *Myrcianthes cisplatensis* (68% of all subplots) *Acacia praecox* (47%), *Achatocarpus praecox* (42%), *Schinopsis balansae* (29%), and *Sideroxylon obtusifolium* (27%).

Seedling richness was higher at intermediate canopy index (Fig. 3).

Forest understorey structure

Bromeliad understorey was highly constant in all plots (100%) and subplots (99.44% ± 0.24), but its cover was low (average±s.e.m. = 13.62% ± 0.42) and quite variable (CV = 91.63). On average, *Aechmea distichantha* cover (6.10% ± 0.32) was similar to *Bromelia serra* cover (7.58% ± 0.26), but it was more variable (CV 158.94 vs 101.85), mainly due to its lower presence (58.6% vs 97.0%). Maximum bromeliad cover was 75%, being slightly higher for *Aechmea distichantha* (65%) than for *Bromelia serra* (55%).

Bromeliad density in the understorey averaged 14.11 individuals/4m^2 (range 0-31 individuals/4m^2), being higher for *Bromelia serra* (9.30 individuals/4m^2) than for *Aechmea distichantha* (4.81 individuals/4m^2). Even though both species shared almost all subplots (99%), their plant densities were negatively correlated (Fig. 4).
Bromeliad cover was higher at intermediate canopy index (Fig. 5). The distribution of *Bromelia serra* seemed to be more skewed to lower canopy index values than *Aechmea distichantha* (Fig. 5).
Seedling richness seemed to be higher at lower bromeliad cover, and this pattern was more noticeably for *Aechmea distichantha* (Fig. 6).
Almost all the previous variables were spatially associated. As an example, Fig. 7 showed the spatial distribution of canopy index, bromeliad cover, seedlings, and saplings from one plot (#9), where the spatial distribution of both bromeliad species seemed to be negatively associated.

Top Soil

Even though bulk density was quiet variable, there were no significant differences among plots (Fig. 8; $F_{15,48}$ = 1.20; P = 0.301). Differences in soil moisture among plots were even higher, but the Kruskall Wallis test did not find a significant difference (Fig. 7; H = 23.62 DF = 15 P = 0.072).
Top soil of these plots (Fig. 9) had a high content of organic matter (average 5.6% ± 0.19; CV 13.53), conductivity (average 123.4 micromhos/cm ± 3.9; CV 12.71), lightly acid pH (average 5.8 ± 0.06; CV 4.16), and phosphorus (average 59.6 ppm ± 4.035; CV 27.07).

2- Convex areas dominated by *Aechmea distichantha* or *Bromelia serra*

Soil analyses and mycorrhizae

Sectors dominated by *Aechmea distichantha* had lower bulk density (Fig. 10; $F_{1,15}$ = 100,71; P < 0,0001) and greater organic matter content (Fig. 10; t = 4,65; P < 0,001) than sectors dominated by *Bromelia serra*. However, there were no significant differences with regard to soil moisture content (Fig. 10; $F_{1,15}$ = 1,55; P = 0,2323), conductivity (Fig. 10; t = 0,02; P = 0,982), pH (Fig. 10; t = -0,58; P = 0,568), or phosphorus (Fig. 10; t = 0,76; P = 0,457).

The richness of Glomeromycota recorded in the rizosphere of both bromeliad species was low, belonging mainly to the genera *Glomus* (i.e: *G. clarum*) and *Acaulospora* (i.e. *A.* aff. *delicata*). We recorded the presence of vesiculo-arbuscular hyphae associated with roots of both species.

3- Edge or understorey of convex areas covered with bromeliads

Environmental variables

Air temperature in open areas was higher than in forest edges and the understorey (Fig. 11; H = 6.41; P = 0.041). Likewise, maximum wind speed was highest in open areas, intermediate in forest edges, and lowest in the understorey (Fig. 11; H = 9.50; P = 0.009). Relative humidity was slightly higher in the understorey than in forest edges and open areas (Fig. 11; H = 6.06; P = 0.048).

Arthropod community within tanks of Aechmea distichanta *plants*

At a similar biomass, sun-grown plants were shorter, had a smaller diametre, capture more water and less organic matter (OM), and had a lower pH than shade-grown plants (Fig. 12). We captured 1975 individuals belonging to 65 morphospecies of 45 families and 16 orders. Most common species belonged to Formicidae, Scirtidae, Lycosidae, Lumbricidae, Araneidae, Culicidae, and Tipulidea.
Macrofauna abundance/mL of water was similar in sun and shade-grown plants, but abundance/mg OM was higher in sun-grown plants (Fig. 13). Species richness and diversity were lower in sun-grown plants (S =44; H´=1.68) than in shade-grown plants (S =61; H´=2.67). The same pattern emerged when rarefaction curves were used (Fig. 14). Beta diversity was similar between sun (ß = 3.5) and shade-grown plants (ß = 3.6). Species composition differed between habitats (P = 0.04;

Table 2). The Formicidae and Scirtidae species were more common in the sun-grown plants, whereas the Lycosidae, Culicidae and Lumbricidae were more common in the shade-grown plants.
The most common trophic groups were detritivores, herbivores and predators, being parasites very rare (2 species). Species distribution by trophic group was similar between sun- and shade-grown plants (Table 3). Individual abundance by trophic group could not be evaluated, because in sun-grown plants there was a high number of one unknown species that obscured the pattern.

DISCUSSION

1- Convex areas covered by bromeliad understory

The results of this project showed high similarity with previous studies. Woody species composition of our plots was similar to the species composition of the convex plots analysed by Lewis et al. (1997) and Barberis et al. (1998, 2002). Moreover, we found all species, but *Celtis iguanea*, recorded by Barberis et al. (2002). Like in previous studies, the most common species for all size classes were *Myrcianthes cisplatensis* and *Acacia praecox* (Barberis 1998, Barberis et al. 2002, 2005).
Soil data from our plots were also similar to the results showed for convex areas in a nearby plot (Barberis et al. 2005). These results confirm that the top soil of these areas is neutral to slightly acid, with intermediate content of organic matter and phosphorus.

2- Convex areas dominated by *Aechmea distichantha* or *Bromelia serra*

Plots showed high internal heterogeneity with regards to bromeliad cover, canopy cover, and seedling distribution. These patterns seem to be spatially associated (Barberis and Lewis 2005), and emphasize the importance of environmental characterization before allocating the plots to each treatment combination (i.e. bromeliad removal and fencing).
In the rizosphere of both bromeliad species we recorded the presence of vesiculo-arbuscular hyphae from the genera *Glomus* and *Acaulospora*. Differences in bromeliad species distribution within each plot seemed not to be associated with most soil chemical properties. Nevertheless, the convex areas dominated by *Aechmea distichantha* had lower bulk density and higher organic matter content than areas dominated by *Bromelia serra*. Our personal observations suggest that their spatial distributions are related to microtopography within each plot. *Aechmea distichantha* is frequently observed in upper sites such as old anthills of *Atta vollenweiderii*. Therefore, we think that it would be worth doing a detailed analysis of plot microtopography.

3- Edge or understorey of convex areas covered with bromeliads

Inside the tanks of *Aechmea distichantha* plants lives a numerous and diverse macrofauna. This is related to the ability of bromeliads to hold rain water and organic matter inside their tanks (Zotz and Thomas 1999, Benzing 2000, Zotz and Hietz 2001). Thus, bromeliads makedly increase ecosystem biodiversity (Armbruster et al. 2002, Blüthgen et al. 2000, Kitching 2000, Lichwart 1994, Mestre et al. 2001, Palacios-Vargas and Castaño-Meneses 2002, Richardson et al. 2000 a,b, Richardson 1999, Sillet 1994, Zillikens et al. 2001). As a consequence, removal of bromeliad colonies for ease cattle management, would have a negative effect on arthropod diversity, as well as on higher trophic levels.
Within convex areas with bromeliads, environmental conditions depend on the spatial location. In forest edges ligh intensity is higher, wind speed is lower and air temperature is higher than in the understorey. Bromeliads show high morphological and physiological plasticity when grown in different environments (Benzing 2000). Plants grown in sun conditions are shorter, more erect and have lower canopy area than plants grown in the understorey (Lee et al. 1989, Scarano et al. 2002; Freitas et al. 2003). These differences between phenotypes seem to be a response of leaf size, width, and angles to different light intensities (Scarano et al. 2002, Cavallero 2005). In this way, sun plants are able to avoid light incidence on most leaf area. This leaf display also lets plants to hold more water inside their tanks. In contrast, shade plants with more open tank, narrower leaves and lower leaf overlap, are able to capture more light in the understorey (Scarano et al. 2002, Freitas et al. 2003).
Thus, due to phenotypic plasticity of *Aechmea distichantha* plants (Cavallero 2005, Cavallero and Barberis 2005), the habitat where these plants develop affects not only the abundance, but also the macrofauna composition (Montero et al. 2005).

Summing up, the results of our project, even though not finished yet, show that the convex areas of the *Schinopsis balansae* forests are very diverse and heterogeneous. Thus, any management practice should take into account all these factors. On the other hand, the effect of cattle on arthropod diversity has been poorly studied (Cagnolo et al. 2002, González-Megias et al. 2004, Mysterud et al. 2005).
A better understanding of the direct and indirect effects of bromeliad colonies and cattle on plant regeneration and biodiversity is essential for the Chaco conservation. The resulting knowledge may allow to design sustainable management strategies at the local level (quebrachal) and to increase the ecological theory (e.g. biotic refuges; Milchunas and Noy Meir 2002, Rebollo et al. 2002, Rebollo et al. 2005).

REFERENCES

Adámoli J, Ginzburg R, Torrella S, Herrera P. 2004. Expansión de la frontera agraria en la región chaqueña: el ordenamiento territorial como herramienta para la sustentabilidad. *Gerencia Ambiental* **11**: 810-823.

Alzugaray C, Barberis I, Carnevale N, Di Leo N, Lewis JP, López D. (accepted). Estado actual de las comunidades vegetales de la Cuña Boscosa de Santa Fe. In: Brown AD, Corcuera J (Eds.). *Situación Ambiental Argentina 2005*. Editorial Fundación Vida Silvestre Argentina, Buenos Aires.

Alzugaray C, Carnevale NJ, Di Leo N, López D. 2005. *Mapa de clasificación de unidades de cobertura de vegetación de la Cuña Boscosa Santafesina*. [Classification map of vegetation unit from the Cuña Boscosa Santafesina]. Tercer Congreso Nacional sobre Manejo de Pastizales Naturales. Paraná, Entre Ríos, 12-14 October 2005.

Armbruster P, Hutchinson RA, Cotgreave P. 2002. Factors influencing community structure in a South American tank bromeliad fauna. *Oikos* 96: 225-234

Barberis IM, Batista WB, Pire EF, Lewis JP, León RJC. 2002. Woody population distribution and environmental heterogeneity in a Chaco forest, Argentina. *Journal of Vegetation Science* **13:** 607-614.

Barberis IM, Lewis JP, Batista WB. 2005. *Heterogeneidad estructural de los bosques de la Cuña Boscosa de Santa Fe en distintas escalas espaciales*. In: Oesterheld M, Aguiar M, Ghersa C, Paruelo J (Eds.). La heterogeneidad de la vegetación de los agroecosistemas. Un homenaje a Rolando León. Pp. 47-62. Editorial: Facultad de Agronomía, UBA.

Barberis IM, Lewis JP. 2005. Heterogeneity of terrestrial bromeliad colonies and regeneration of *Acacia praecox* (Fabaceae) in a humid-subtropical-Chaco forest, Argentina. *Revista de Biología Tropical* **53**: 377-385.

Barberis IM, Pire EF, Lewis JP. 1998. Spatial heterogeneity and woody species distribution in a *Schinopsis balansae* (Anacardiaceae) forest of the Southern Chaco, Argentina. *Revista de Biología Tropical* **46**: 515-524.

Barberis IM. 1998. *Distribución y regeneración de especies leñosas en relación con la heterogeneidad ambiental en un bosque de* Schinopsis balansae *del sur del Chaco Oriental*. Magister Scientiae en Recursos Naturales, Universidad de Buenos Aires, Buenos Aires, Argentina.

Benzing DH. 2000. *Bromeliaceae. Profile of an Adaptive Radiation*. Cambridge: Cambridge University Press.

Bertonatti C, Corcuera J. 2000. *Situación ambiental Argentina 2000*. Fundación Vida Silvestre Argentina, Buenos Aires.

Bitlloch E, Sormani HA. 1997. Los enclaves forestales de la región chaqueño-misionera. *Ciencia Hoy* **7**: 41-52.

Blüthgen N, Verhaagh M, Goitia W, Blüthgen N. 2000. Ant nests in tank bromeliads - an example of non-specific interaction. *Insectes Sociaux* 47: 313-316.

Bordón AO. 1978. *Las bromeliáceas terrestres*. INTA Presidencia Roque Sáenz Peña, Presidencia Roque Sáenz Peña.

Cagnolo L, Molina SI, Valladares GR. 2002. Diversity and guild structure of insect assemblages under grazing and exclusion regimes in a montane grassland from Central Argentina. *Biodiversity and Conservation* 11: 407-420.

Cavallero L, Barberis IM. 2005. El caraguatá: un habitante del sotobosque del quebrachal. *EcoLógica* **8**: 6-9.

Cavallero L. 2005. *Variaciones morfológicas de* Aechmea distichantha *Lem. (Bromeliaceae, Bromelioideae) al sol y a la sombra, y su relación con la captación, acumulación y pérdida de agua*. Bachelor thesis, Universidad Nacional del Litoral, Santa Fe.

Espino LM, Seveso MA, Sabatier MA. 1983. *Mapa de suelos de la provincia de Santa Fe.* Tomo II. Buenos Aires: MAG Santa Fe e INTA EERA Rafaela, Argentina.

Freitas CA, Scarano FR, Biesboer DD. 2003. Morphological variation in two facultative epiphytic bromeliads growing on the floor of a swamp forest. *Biotropica* **35**: 546-550.

González-Megías A, Gómez J, Sánchez-Piñero F. 2004. Effects of ungulates on epigeal arthropods in Sierra Nevada National Park (southeast Spain). *Biodiversity and Conservation* 13: 733-752.

Gotelli NJ, Entsminger GL. 2002. *EcoSim: Null Models Software for Ecology, version 7*. Acquired Intelligence Inc. and Kesey-Bear, Burlington.

Gotelli NJ, Graves GR. 1996. *Null models in ecology*. Smithsonian Institution Press, Washington.

Kitching RL. 2000. *Food Webs and Container Habitats. The Natural History and Ecology of Phytotelmata*. Cambridge University Press, Cambridge.

Lee HSJ, Lüttge U, Medina E, Smith JAC, Cram WJ, Díaz M, Griffiths H, Popp M, Schäfer C, Stimmel K-H, Thonke B. 1989. Ecophysiology of xerophytic and halophytic vegetation of a coastal alluvial plain in northern Venezuela. III. *Bromelia humilis* Jacq., a terrestrial CAM bromeliad. *New Phytologist* 111: 253-271.

Lewis JP, Pire EF, Barberis IM. 1997. Structure, physiognomy and floristic composition of a *Schinopsis balansae* (Anacardiaceae) forest in the Southern Chaco, Argentina. *Revista de Biología Tropical* **45**: 1013-1020c.

Lewis JP, Pire EF. 1981. *Reseña sobre la vegetación del Chaco santafesino*. Serie Fitogeográfica 18. Instituto Nacional de Tecnología Agropecuaria, Buenos Aires, Argentina.

Lewis JP. 1991. Three levels of floristical variation in the forests of Chaco. *Journal of Vegetation Science* **2**: 125-130.

Lewis JP. 1991. Three levels of floristical variation in the forests of Chaco. *Journal of Vegetation Science* **2**: 125-130.

Lichwardt RW. 1994. Trichomycete fungi living in the guts of Costa Rican phytotelm larvae and other lentic dipterans. *Revista de Biología Tropical* 42: 31-48.

Martínez Crovetto R. 1980. Estudios fitosociológicos en el sotobosque de los quebrachales del noroeste de Corrientes (República Argentina). *Boletín de la Sociedad Argentina de Botánica* **19**: 315-329.

McCune B, Mefford MJ. 1999. *Multivariate analysis of ecological data*. Gleneden Beach: MjM Software.

Mestre LAM, Aranha JMR, Esper MDP. 2001. Macroinvertebrate fauna associated to the bromeliad Vriesea inflata of the Atlantic Forest (Parana State, southern Brazil). *Brazilian Archives of Biology and Technology* 44: 89-94.

Milchunas DG, Noy-Meir I. 2002. Grazing refuges, external avoidance of herbivory and plant diversity. *Oikos* 99: 113-130.

Montero G, Feruglio C, Barberis I. 2005. Abundancia, riqueza y diversidad de macrofauna en plantas de *Aechmea distichantha* ubicadas al sol y a la sombra en un quebrachal del Chaco santafesino. [Macrofauna abundance, richness and diversity in *Aechmea distichantha* plants grown in sun and shade conditions in a quebrachal of the Chaco santafesino]. VI Congreso Argentino de Entomología. San Miguel de Tucumán, 12-15 September 2005.

Mysterud A, Hansen LO, Peters C, Austrheim G. 2005. The short-term effect of sheep grazing on selected invertebrates (Diptera and Hemiptera) relative to other environmental factors in an alpine ecosystem. *Journal of Zoology* 266: 411-418.

Palacios-Vargas JG, Castaño-Meneses G. 2002. Collembola associated with *Tillandsia violacea* (Bromeliaceae) in Mexican *Quercus-Abies* forests. *Pedobiologia* 46: 395-403.

Pire EF, Prado DE. 2000. *Pautas empíricas para un manejo sustentable de los bosques de la cuña boscosa santafesina*. In: Bertonatti C, Corcuera J. Situación ambiental argentina 2000. pp. 257-260. Editorial Fundación Vida Silvestre Argentina, Buenos Aires.

Quinn GP, Keough MJ. 2002. *Experimental design and data analysis for biologists*. Cambridge: Cambridge University Press.

Rebollo S, Milchunas DG, Noy-Meir I, Chapman PL. 2002. The role of a spiny plant refuge in structuring grazed shortgrass steppe plant communities. *Oikos* 98: 53-64.

Rebollo S, Milchunas DG, Noy-Meir I. 2005. Refuge effects of a cactus in grazed short-grass steppe. *Journal of Vegetation Science* 16: 85-92.

Richardson BA, Richardson MJ, Scatena FN, McDowell WH. 2000a. Effects of nutrient availability and other elevational changes on bromeliad populations and their invertebrate communities in a humid tropical forest in Puerto Rico. *Journal of Tropical Ecology* 16: 167-188.

Richardson BA, Rogers C, Richardson MJ. 2000b. Nutrients, diversity, and community structure of two phytotelm systems in a lower montane forest, Puerto Rico. *Ecological Entomology* 25: 348-356.

Richardson BA. 1999. The bromeliad microcosm and the assessment of faunal diversity in a Neotropical forest. *Biotropica* 31: 321-336.

SAS Institute Inc. 1999. *SAS System version 8*. Cary: SAS Institute Inc.

Scarano FR, Duarte HM, Rôças G, Barreto SMB, Amado EF, Reinert F, Wendt T, Mantovani A, Lima HRP, Barros CF. 2002. Acclimation or stress symptom? An integrated study of intraspecific variation in the clonal plant *Aechmea bromeliifolia*, a widespread CAM tank-bromeiliad. *Botanical Journal of the Linnean Society* **140**: 391-401.

Sillet TS. 1994. Foraging ecology of epiphyte-searching insectivorous birds in Costa Rica. *The Condor* 96: 863-877.

Whittaker RH. 1967. Gradient analysis of vegetation. *Biological Reviews* **42**: 207-264.

Zillikens A, Steiner J, Mihalko Z. 2001. Nests of *Augochlora* (A.) *esox* in bromeliads, a previously unknown site for sweat bees (Hymenoptera : Halictidae). *Studies on Neotropical Fauna and Environment* 36: 137-142.

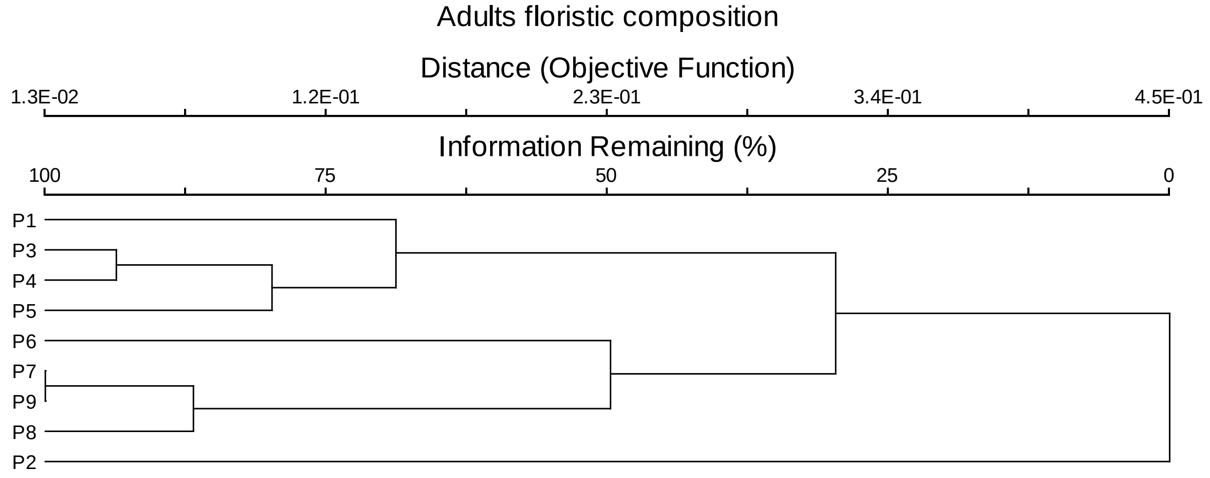
Zotz G, Hietz P. 2001. The physiological ecology of vascular epiphytes: current knowledge, open questions. *Journal of Experimental Botany* 52: 2067-2078.

Zotz G, Thomas V. 1999. How much water in in the tank? Model calculations for two epiphytic bromeliads. *Annals of Botany* 83: 183-192.

Table 1. Relative density of individuals > 1 cm dbh, large saplings, small saplings and seedlings of woody species among different habitats. First row: Results based on MRPP tests comparing size classes of woody species according to their species composition in different plots. Size classes with a different letter are significantly different at a P-level of 0.05 according to MRPP tests. Values show the relative density of individuals of each species in each size class, and the column total shows total density (individuals), species richness and beta diversity of each size class.

	MRPP results	a	b	b	c
Species	Family	> 1 cm dbh	> Saplings	< Saplings	Seedlings
Myrcianthes cisplatensis O. Berg	Myrtaceae	39.55	26.29	34.80	48.40
Achatocarpus praecox Griseb.	Achatocarpaceae	15.42	4.22	1.62	0.56
Acacia praecox Griseb.	Fabaceae	14.76	22.90	23.78	22.32
Celtis pallida Torr.	Celtidaceae	5.84	9.09	3.46	1.71
Sideroxylon obtusifolium (Roem. & Schult.) T.D. Penn.	Sapotaceae	5.09	5.73	3.77	7.75
Maytenus vitis-idaea Griseb.	Celastraceae	4.25	3.55	2.61	0.85
Coccoloba argentinensis Speg.	Polygonaceae	3.32	9.30	5.43	1.42
Schinopsis balansae Engl.	Anacardiaceae	2.65	0.00	0.18	0.17
Ziziphus mistol Griseb.	Rhamnaceae	1.93	0.71	0.00	0.44
Schinus fasciculata (Griseb.) I.M. Johnst.	Anacardiaceae	1.57	2.92	2.66	1.38
Capparis retusa Griseb.	Capparaceae	1.53	3.51	7.65	4.76
Aspidosperma quebracho-blanco Schltdl.	Apocynaceae	1.15	2.06	4.85	6.94
Prosopis spp.	Fabaceae	1.01	0.00	0.00	0.06
Acanthosyris falcata Griseb.	Santalaceae	0.52	1.99	0.12	0.00
Erythroxilum microphyllum A. St.-Hil.	Erythroxylaceae	0.45	5.39	3.83	1.28
Banara umbraticola Arechav.	Flacourtiaceae	0.28	0.15	1.02	0.47
Ruprechtia laxiflora Meisn.	Polygonaceae	0.27	0.00	0.00	0.00
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	0.21	0.24	0.84	0.79
Schinus fasciculata (Griseb.) I.M. Johnst. var. *fasciculata*	Anacardiaceae	0.12	0.33	0.00	0.00
Caesalpinia paraguariensis (D. Parodi) Burkart	Fabaceae	0.07	0.00	0.10	0.15
Holmbergia tweedii (Moq.) Speg.	Chenopodiaceae	0.00	0.57	0.59	0.30
Unknown		0.00	0.33	1.34	0.25
Aloysia gratissima (Gillies & Hook.) Tronc.	Verbenaceae	0.00	0.72	0.49	0.00
Lycium cuneatum Dammer	Solanaceae	0.00	0.00	0.12	0.00
Grabowskia duplicata Arn.	Solanaceae	0.00	0.00	0.74	0.00
Total		912	324	859	1242
Species richness		20	19	21	19
Beta diversity		1.91	2.22	1.93	1.97

Fig. 1. Dendrograms of plots grouped according to the abundance of adults and seedlings. We used farthest neighbour as the linkage method and Sörensen as the distance measure



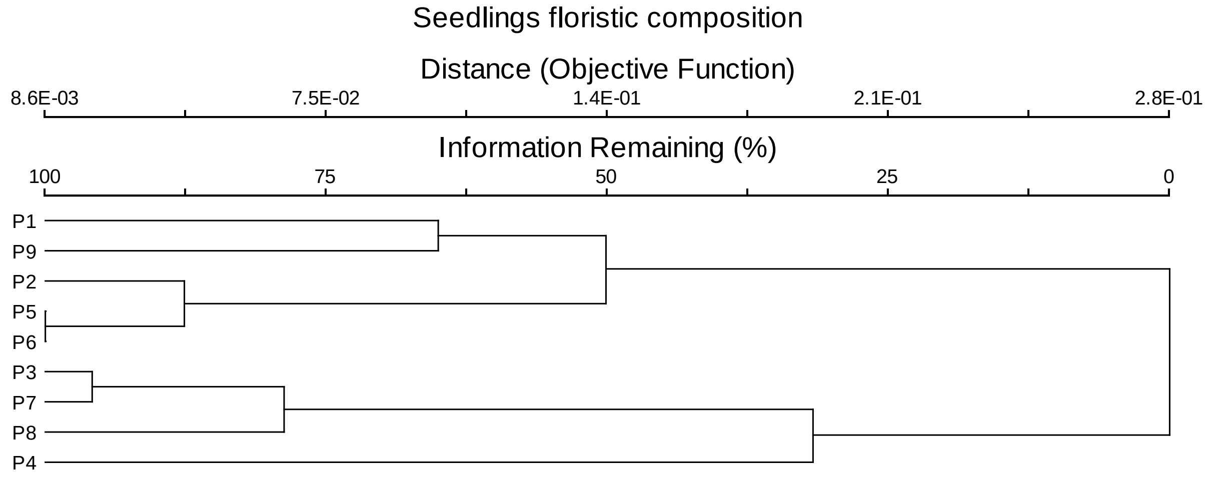


Fig. 2. Frequency distribution of subplots according to the canopy index (scale 1=completely open to 5=completely covered). Bars denote s.e.m.

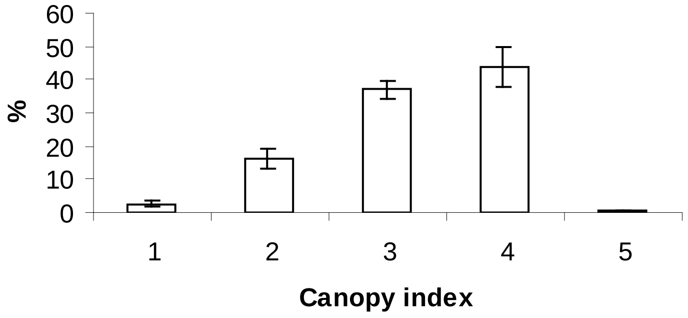


Fig. 3. Seedling richness distribution according to the canopy index. Each circle represents a subplot. Canopy index scale (scale 1=completely open to 5=completely covered).

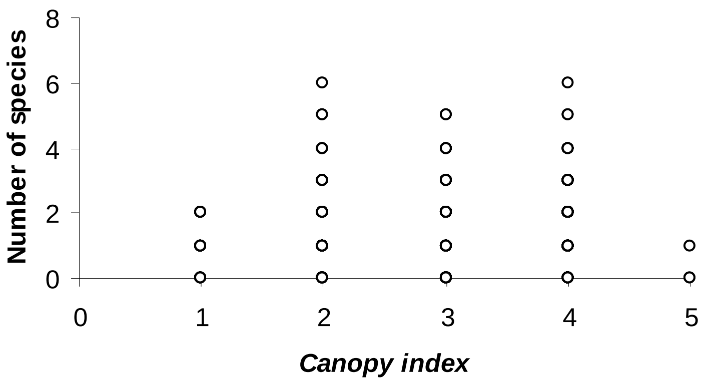


Fig. 4. Correlation between plant densities of *Bromelia serra* and *Aechmea distichantha*. Each circle represents a subplot.

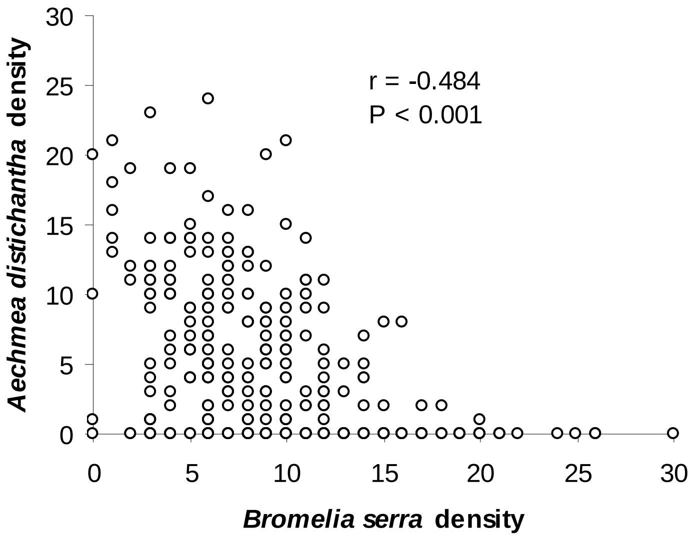


Fig. 5. Bromeliad, *Aechmea distichantha* and *Bromelia serra* cover distribution according to the canopy index. Each circle represents a subplot. Canopy index scale (scale 1=completely open to 5=completely covered).

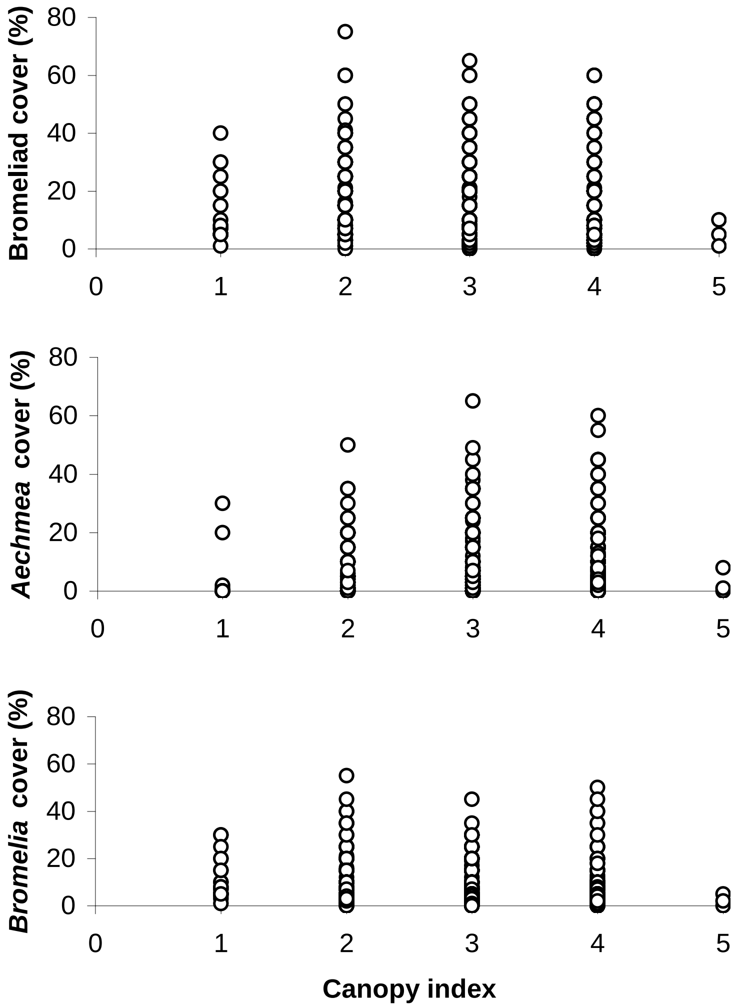


Fig. 6. Seedling species richness distribution according to Bromeliad, *Aechmea distichantha* and *Bromelia serra* cover. Each circle represents a subplot

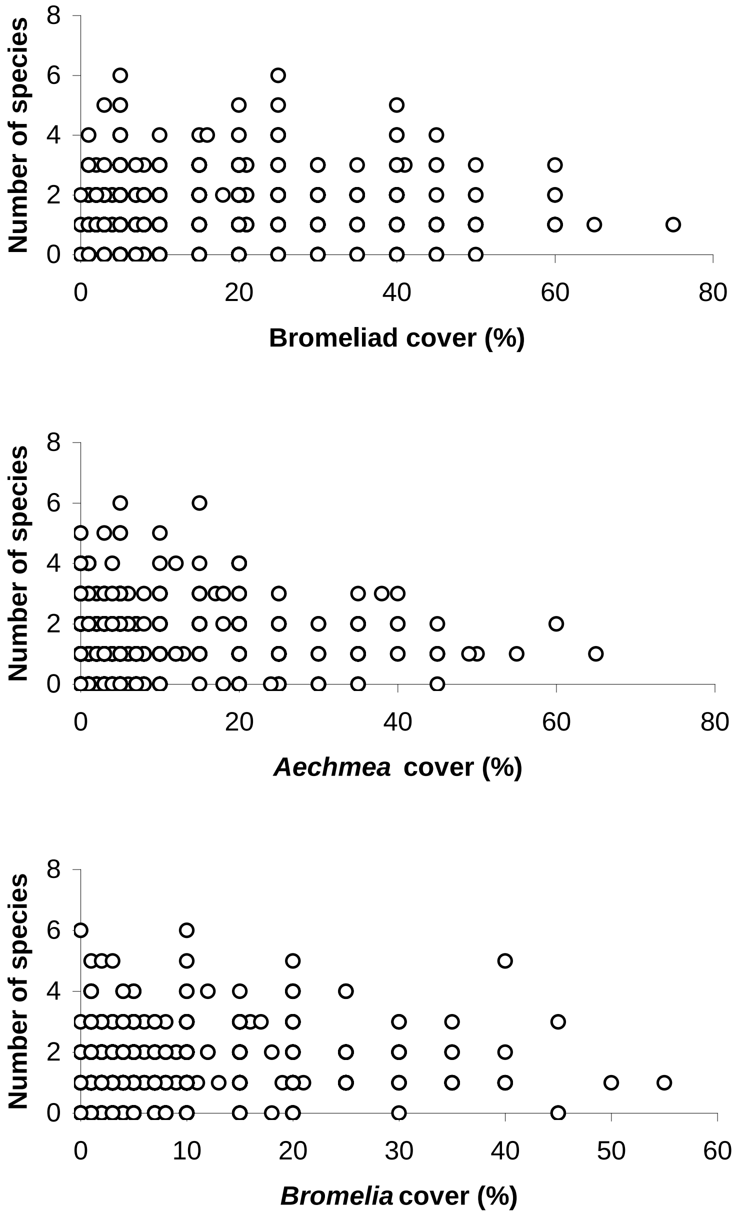


Fig. 7. Spatial distribution of canopy index, bromeliad cover, *Aechmea distichantha* cover, *Bromelia serra* cover, and the species richness of seedling, small and large saplings for plot number 9. Each grid consisted of 100 subplots. For all grids, each number represents the value of the considered variable in a subplot.

Canopy index

4	4	4	4	4	4	4	4	4	4
3	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4
4	4	3	4	4	4	4	4	4	3
3	2	3	3	4	4	4	4	4	3
3	2	2	3	4	4	3	4	3	4
4	3	3	4	3	3	2	2	3	3
3	3	3	3	3	3	3	3	3	4
4	3	3	3	4	4	4	3	3	3
4	3	4	3	4	4	4	4	3	3

Bromeliad cover (%)

1	3	5	1	2	3	2	3	2	2
2	5	4	3	2	3	1	3	0	3
3	3	1	20	2	3	3	5	5	2
5	5	3	3	5	2	5	3	2	5
5	7	7	7	4	1	2	2	1	1
5	20	7	10	15	2	3	4	2	5
3	5	20	45	25	20	7	10	10	7
10	8	30	8	25	10	40	20	5	10
5	5	8	10	15	8	8	5	7	10
5	3	8	5	8	8	8	5	10	7

Aechmea distichantha cover (%)

0	0	0	0	0	0	0	0	0	0
0	0	0	3	0	0	0	0	0	0
0	0	0	18	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0
0	4	3	3	1	0	0	0	0	0
0	10	1	4	13	1	1	2	0	4
0	0	15	0	24	20	3	7	8	5
8	4	25	8	20	7	35	15	4	8
2	3	4	10	12	5	5	1	4	7
5	3	7	5	5	8	4	3	10	7

Bromelia serra cover (%)

1	3	5	1	2	3	2	3	2	2
2	5	4	1	2	3	1	3	0	3
3	3	1	2	2	3	3	5	5	2
5	4	2	2	5	2	5	3	2	5
5	3	4	4	3	1	2	2	1	1
5	10	7	7	2	2	3	2	2	1
3	5	5	45	1	1	4	3	2	2
2	4	5	1	5	3	5	5	1	2
3	2	4	1	3	3	3	4	3	3
1	1	1	0	3	1	4	2	0	0

Canopy index

4	4	4	4	4	4	4	4	4	4
3	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4
4	4	3	4	4	4	4	4	4	3
3	2	3	3	4	4	4	4	4	3
3	2	2	3	4	4	3	4	3	4
4	3	3	4	3	3	2	2	3	3
3	3	3	3	3	3	3	3	3	4
4	3	3	3	4	4	4	3	3	3
4	3	4	3	4	4	4	4	3	3

Seedlings

2	1	1	3	2	2	3	1	1	2
1	1	2	2	2	2	1	5	2	3
2	2	1	3	2	2	2	2	2	2
1	4	2	3	3	1	1	1	2	1
1	1	3	3	1	1	1	2	3	4
1	1	1	3	1	2	1	1	1	2
1	2	1	0	0	0	1	0	1	1
1	1	1	1	0	0	2	1	1	1
1	2	1	2	1	2	1	2	1	1
1	1	1	1	0	0	2	1	1	0

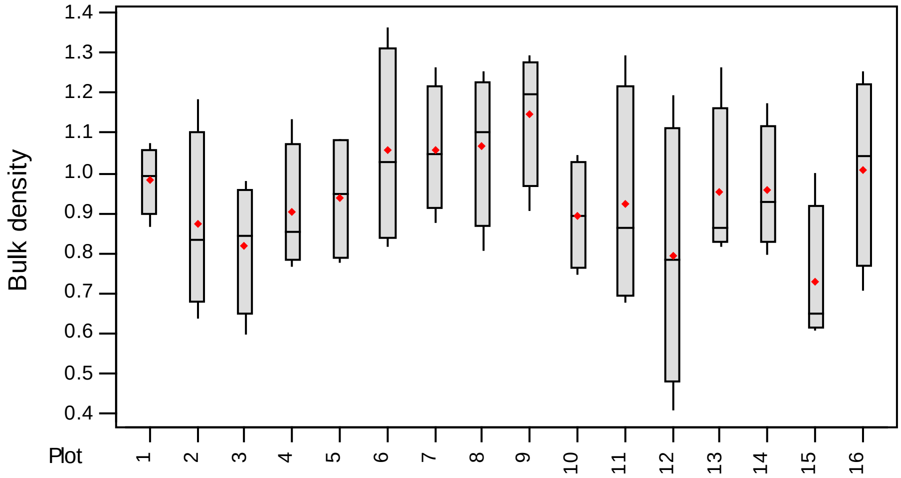
Small saplings

0	1	2	1	1	0	0	1	0	0
0	1	2	2	0	0	0	1	0	1
1	3	0	1	0	1	1	1	0	4
0	1	1	0	2	0	2	1	1	3
2	0	1	0	2	1	0	0	0	1
1	0	0	1	1	1	2	1	2	3
0	1	2	3	2	1	2	1	2	1
1	0	1	4	1	1	1	1	3	2
0	1	3	2	2	0	0	1	1	1
2	0	1	2	1	1	2	0	0	1

Large Saplings

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1
0	0	0	1	2	0	0	0	0	2
0	0	2	1	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0
0	1	2	1	0	2	0	1	2	1
1	0	0	1	1	1	2	0	0	0
0	0	1	2	0	0	1	0	0	0
0	0	0	0	0	1	0	1	0	0

Fig. 8. Bulk density (g/cm^3) and gravimetric water content (%) of top soil for the 16 analysed plot. Bars denote median and quartiles. The red dots indicate the average.



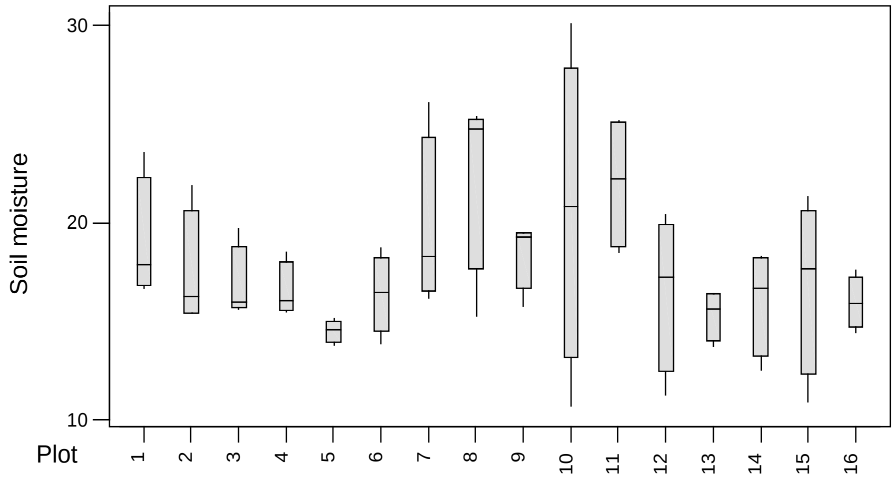


Fig. 9. Phosphorus (ppm), organic matter (%), conductivity (micromhos/cm), and pH for the 16 analysed plot. Each bar is the result of a composite sample (n=12).

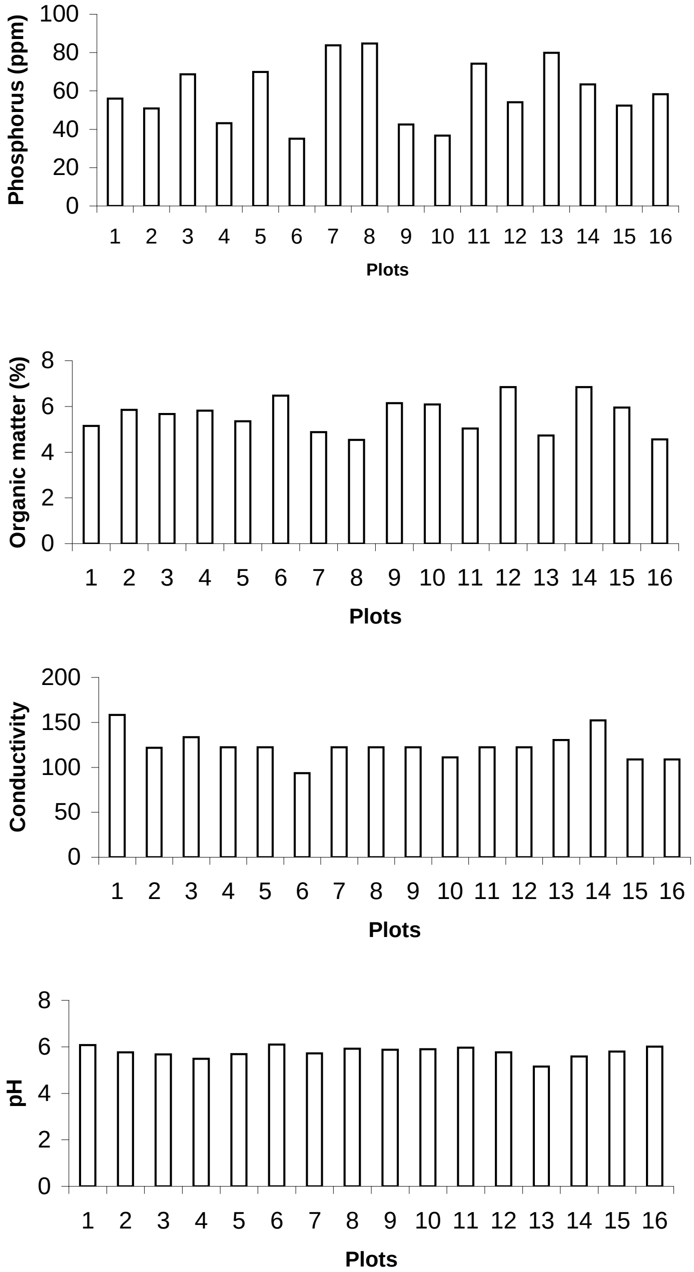


Fig. 10. Physical and chemical properties of top-soil from understorey sectors dominated by *Aechmea distichantha* (Ad) or *Bromelia serra* (Bs).

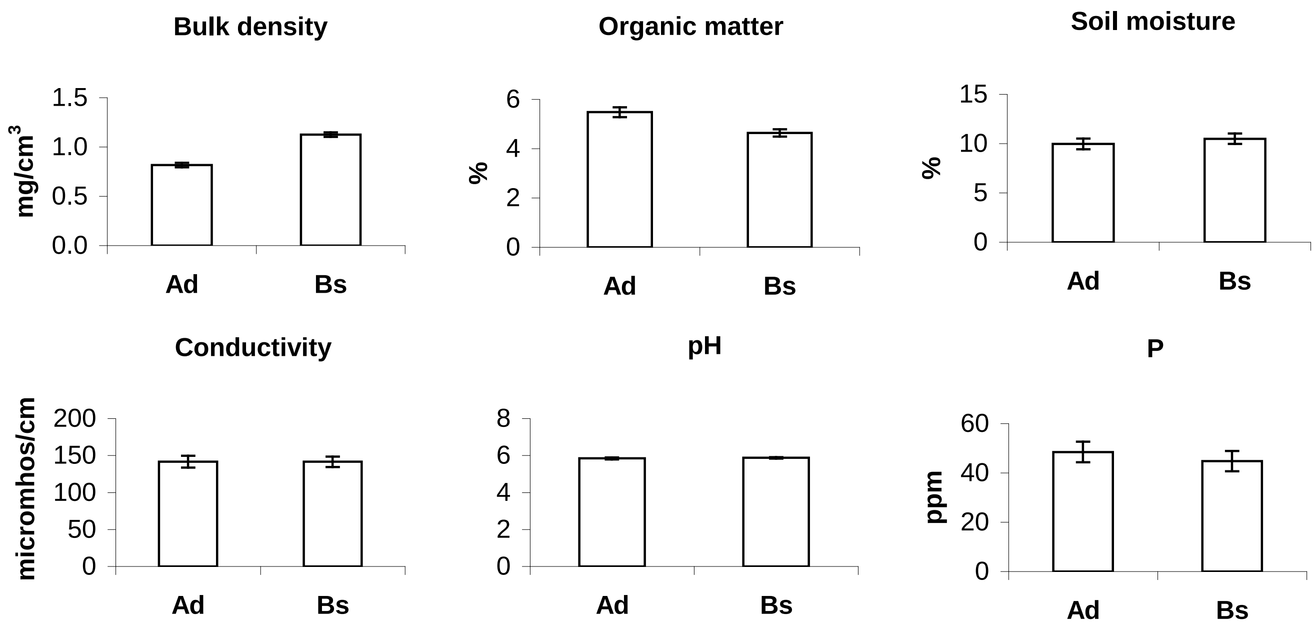


Fig. 11. Climatic variables (temperature, wind speed, and relative humidity) in the understorey, at the edge, and in open areas of the *Schinopsis balansae* forests.

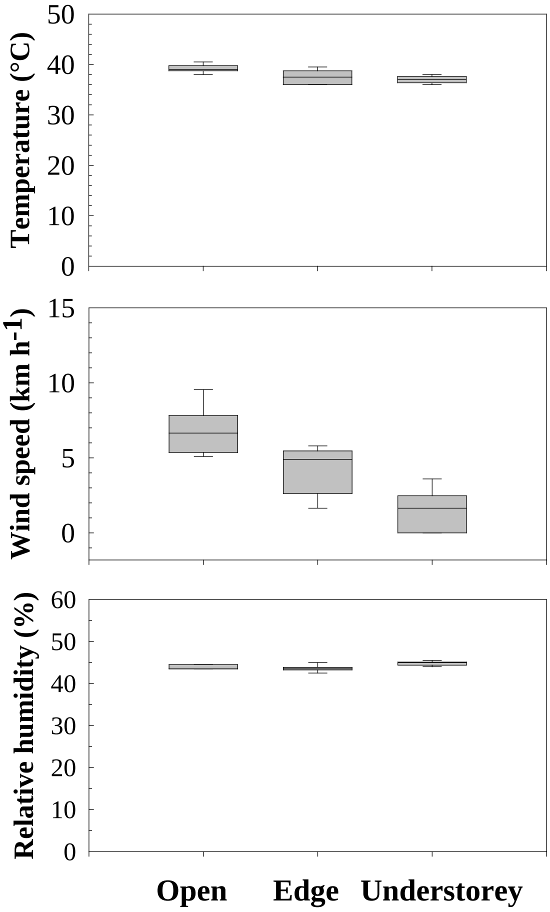


Fig. 12. Phytotelma characteristics (pH, water volume, organic matter, temperature) for *Aechmea distichantha* plants grown under shade- and sun-conditions (understorey and edge habitats respectively).

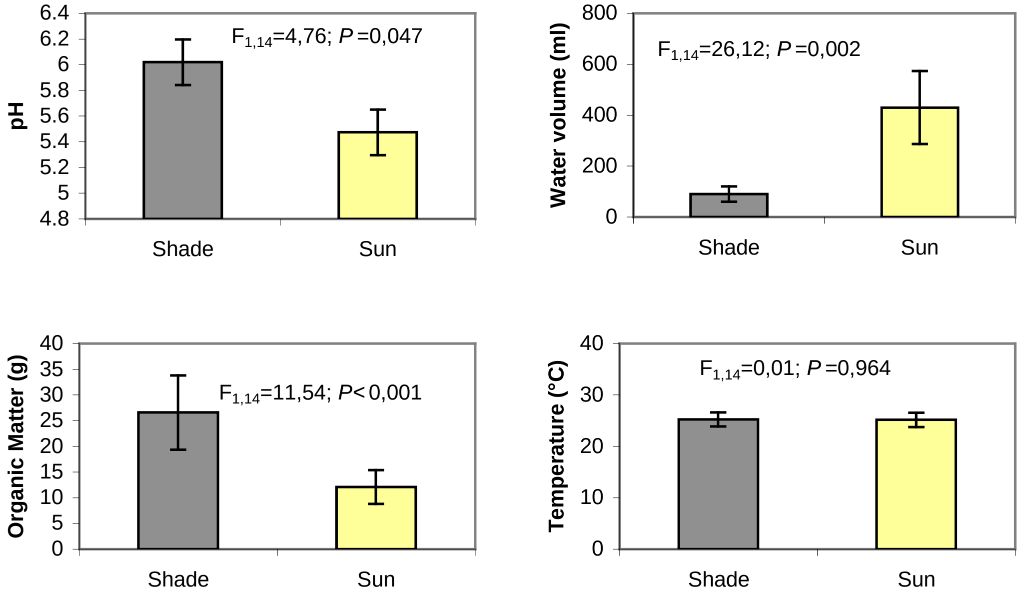


Fig. 13. Macrofauna abundance and derived variables (i.e. abundance/g bromeliad, abundance/ml water, abundance/g organic matter) recorded in the phytotelma of *Aechmea distichantha* plants grown under shade- and sun-conditions (understorey and edge habitats respectively).

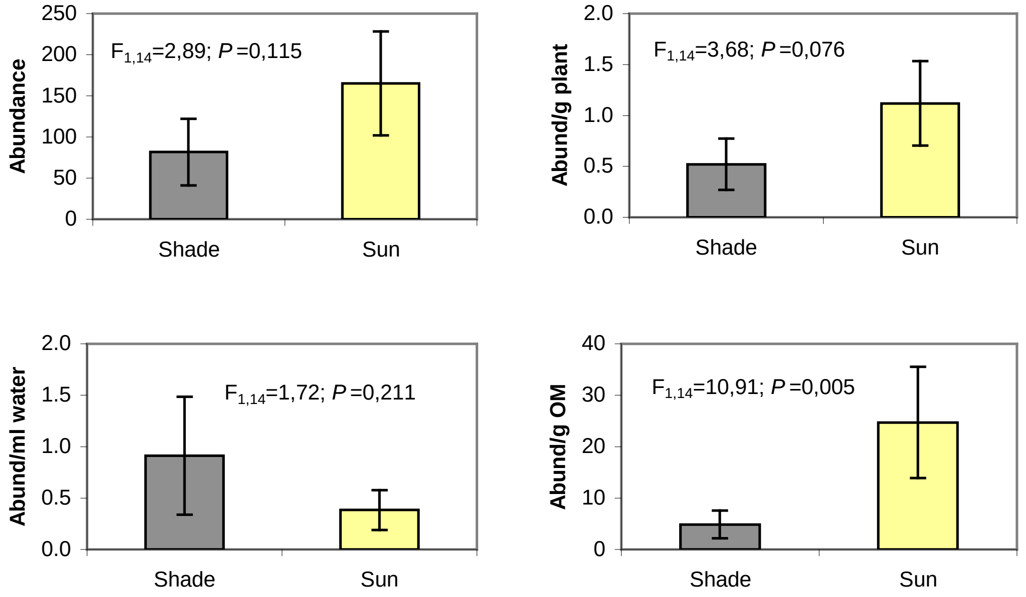


Fig. 14. Rarefaction curves for total arthropod species richness dwelling inside the tanks of *Aechmea distichantha* plants grown in the sun and in the shade. Vertical lines denote 95% confidence intervals.

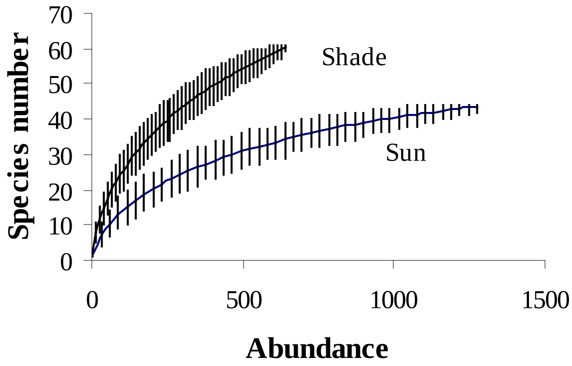


Table 3. Richness and abundance of trophic groups in *Aechmea distichantha* plants grown in the shade and in the sun. Values show percentage of each trophic group within each plant type. The last row shows total richness and total abundance.

Trophic group	Richness			Abundance		
	Shade	Sun	All	Shade	Sun	All
Detritivores	31.7	38.6	30.8	52.6	15.3	27.6
Herbivores	25.0	13.6	24.6	28.7	21.1	23.6
Parasites	1.7	2.3	3.1	0.2	0.1	0.1
Predators	31.7	36.4	32.3	17.3	4.2	8.6
Unknown	10.0	9.1	9.2	1.2	59.3	40.1
Total	60	44	65	654	1321	1975

Table 2. Abundance of different macrofauna morphospecies dwelling inside tanks of *Aechmea distichantha* plants grown in the shade or in the sun. The morphospecies are listed as families with species code number. Species are ordered by trophic groups. Class, order are family are presented for each morphospecies. Growth stage code: (A: adult, L = larvae, N = nymphae). Individuals were sent to specialists for further identification. Bold values denotes more than 20 individuals.

Morphospecie	TG	CLA	ORD	FAM	Habitat Shade	Habitat Sun	Total
Arachnida sp. 241	PRE	CHE	ARA		3	3	**6**
Arachnida sp. 246	PRE	CHE	ARA		1	2	**3**
Araneidae (4 sp.)	PRE	CHE	ARA	ARA	**23**	**21**	**44**
Clubionidae sp. 026	PRE	CHE	ARA	CLU	7	4	**11**
Aglaoctenus lagotis Holmberg	PRE	CHE	ARA	LYC	1	1	**2**
Lycosidae sp. 247	PRE	CHE	ARA	LYC	**34**	7	**41**
Lycosidae sp. 249	PRE	CHE	ARA	LYC	2	3	**5**
Salticidae sp. 022	PRE	CHE	ARA	SAL	12	3	**15**
Salticidae sp. 242	PRE	CHE	ARA	SAL	2	1	**3**
Araneae sp. 176	PRE	CHE	ARA	ARA	1	2	**3**
Sparassidae sp. 112	PRE	CHE	ARA	SPA	1	1	**2**
Acanthocteridae sp. 058	PRE	CHE	ARA	ACA	1	0	**1**
Ctenidae cf. sp. 243	PRE	CHE	ARA	CTE	1	0	**1**
Pseudoescorpionida sp. 159	PRE	CHE	PSE		6	0	**6**
Scorpionida sp. 158	PRE	CHE	SCO		1	1	**2**
Staphilinidae sp. 044	PRE	INS	COL	STA	9	2	**11**
Staphilinidae sp. 172	PRE	INS	COL	STA	1	2	**3**
Staphilinidae sp. 009	PRE	INS	COL	STA	1	0	**1**
Hydrophilidae sp. 114	PRE	INS	COL	HYD	0	3	**3**
Solenopsis sp. 037	PRE	INS	HYM	FOR	10	0	**10**
Vespidae sp. 238	PRE	INS	HYM	VES	0	1	**1**
Hylidae sp. 001	PRE	VER	ANU	HYL	5	1	**6**
Hymenoptera sp. 217	PAR	INS	HYM		1	0	**1**
Evanidae sp. 240	PAR	INS	HYM	EVA	0	1	**1**
Clitrinae sp. 051 (L)	HER	INS	COL	CHR	7	1	**8**
Curculionidae sp. 199	HER	INS	COL	CUR	0	5	**5**
Scirtidae sp. 003 (L)	HER	INS	COL	SCI	**162**	**258**	**420**
Curculionidae sp. 106	HER	INS	COL	CUR	1	0	**1**
Curculionidae sp. 218	HER	INS	COL	CUR	2	0	**2**
Aphodini sp. 223	HER	INS	COL	SCA	1	0	**1**
Scirtidae sp. 236 (A)	HER	INS	COL	SCI	1	0	**1**
Hemiptera sp. 197 (A)	HER	INS	HET		1	3	**4**
Hemiptera sp. 054 (N)	HER	INS	HET		1	0	**1**
Cicadidae sp. 055	HER	INS	HET	CIC	1	0	**1**
Lepidoptera sp. 099 (L)	HER	INS	LEP		5	8	**13**
Lepidoptera sp. 100 (L)	HER	INS	LEP		1	4	**5**
Geometridae sp. 056	HER	INS	LEP	GEO	1	0	**1**
Strymon megarus Godart	HER	INS	LEP	NYM	2	0	**2**
Staleochlora viridicata Serville	HER	INS	ORT	ACR	1	0	**1**
Copiphorinae sp. 057	HER	INS	ORT	COP	1	0	**1**
Blattidae sp. 005	DET	INS	BLA	BLA	8	0	**8**
Nitidulidae sp. 117	DET	INS	COL	NIT	4	1	**5**
Bruchidae sp. 198	DET	INS	COL	BRU	0	1	**1**
Dermaptera sp. 132	DET	INS	DER		4	0	**4**
Chaoboridae sp. 006 (L)	DET	INS	DIP	CHA	6	10	**16**
Chironomidae sp. 237 (L)	DET	INS	DIP	CHI	12	12	**24**
Culicidae sp. 004 (L)	DET	INS	DIP	CUL	**60**	15	**75**
Psychodidae sp.195 (L)	DET	INS	DIP	PSY	2	2	**4**
Stratiomydae sp. 015 (L)	DET	INS	DIP	STR	6	4	**10**
Eristalis sp. 014 (L)	DET	INS	DIP	SYR	16	3	**19**
Tabanidae cf. sp. 016 (L)	DET	INS	DIP	TAB	5	3	**8**
Tipulidae sp. 017 (L)	DET	INS	DIP	TIP	**31**	18	**49**
Diptera sp. 196 (L)	DET	INS	DIP		3	8	**11**
Diptera sp. 216 (L)	DET	INS	DIP		1	4	**5**
Syrphidae sp. 228 (L)	DET	INS	DIP	SYR	1	0	**1**
Embiotera sp. 162	DET	INS	EMB		3	1	**4**
Pheidole sp. 39	DET	INS	HYM	FOR	2	1	**3**
Balloniscus sellowii Brandt	DET	MAL	ISO	BAL	4	0	**4**
Lumbricidae sp.194	DET	OLI	HAP	LUM	3	4	**7**
Lumbricidae sp.193	DET	OLI	HAP	LUM	**165**	**113**	**278**
Coleoptera sp. 118	UKW	INS	COL		1	2	**3**
Coleoptera sp. 191	UKW	INS	COL		2	1	**3**
Coleoptera sp. 192	UKW	INS	COL		1	0	**1**
Formicidae sp. 244	UKW	INS	HYM	FOR	1	**61**	**62**
Formicidae sp. 038	UKW	INS	HYM	FOR	2	**719**	**721**
Species richness					60	44	**65**
Abundance					654	1321	**1975**

V.2. Publications.

V.2.1. Barberis I.M. and J.P. Lewis. 2005. *Revista de Biología Tropical* 53(3-4): 377-385. (Attached file: Barberis & Lewis 2005.pdf)

V.2.2. Cavallero, L. and I.M. Barberis. 2005. *EcoLógica* 8(2): 6-9. (Attached file: Cavallero & Barberis 2005.pdf)

V.2.3. Alzugaray C., I. Barberis, N. Carnevale, N. Di Leo, J.P. Lewis and D. López. (in press). In: Brown A.D. and Corcuera J. (Eds.). *Situación Ambiental Argentina 2005*. Editorial Fundación Vida Silvestre Argentina, Buenos Aires. (Attached file: Alzugaray et al 2006.doc)

V.2.4. Barberis I.M., J.P. Lewis and W.B. Batista. 2005. Heterogeneidad estructural de los bosques de la Cuña Boscosa de Santa Fe en distintas escalas espaciales. In: Oesterheld M., Aguiar M., Ghersa C. and Paruelo J. (Eds.). *La heterogeneidad de la vegetación de los agroecosistemas. Un homenaje a Rolando León*. Pp. 47-62. Editorial: Facultad de Agronomía, UBA. (Attached file: Barberis et al 2005.pdf)

V.3. Abstracts of Congress presentations.

ABUNDANCIA, RIQUEZA Y DIVERSIDAD DE MACROFAUNA EN PLANTAS DE *AECHMEA DISTICHANTHA* UBICADAS AL SOL Y A LA SOMBRA EN UN QUEBRACHAL DEL CHACO SANTAFESINO [Macrofauna abundance, richness and diversity in Aechmea distichantha plants grown in sun and shade conditions in a quebrachal of the Chaco Santafesino]

Montero, G.; Feruglio, C. & Barberis, I.
Facultad de Ciencias Agrarias, U.N.R. CC 14, S2125ZAA, Zavalla.

En los quebrachales de *Schinopsis balansae* del Chaco santafesino crecen densas colonias terrestres de *Aechmea distichantha*. La materia orgánica y el agua de lluvia se acumulan entre las bases de sus hojas (tanque), creando un hábitat propicio para la macrofauna. *Aechmea* desarrolla tanto al sol como a la sombra del sotobosque, pero las plantas presentan diferentes morfologías. El objetivo fue determinar si existían diferencias en la abundancia, riqueza y diversidad de macrofauna entre plantas que crecen en ambos ambientes. En un quebrachal cercano a Las Gamas, Dpto. Vera, Santa Fe, se seleccionaron 8 plantas de cada ambiente. En cada planta se midió altura, diámetros, biomasa y se caracterizó su tanque (pH y temperatura del agua, contenido de agua y de materia orgánica). La macrofauna fue filtrada, separada y se conservó en alcohol al 70% para su posterior identificación. Las características de las plantas y la abundancia de macrofauna fueron analizadas con modelos lineales generalizados y la composición con métodos multivariados (MRPP). A igualdad de biomasa, las plantas que crecen al sol son más bajas, tienen menor diámetro, capturan más agua y menos materia orgánica que las de sombra. En la macrofauna se encontraron 1975 individuos de 66 morfoespecies, 16 órdenes y 46 familias. La abundancia fue similar en plantas de sol y sombra. Si bien la abundancia/ml_{AGUA} fue similar, la abundancia/mg_{MO} fue mayor en plantas de sol. En plantas de sombra se encontraron 654 individuos de 61 especies y en las de sol 1321 individuos de 44 especies. La composición de especies difirió entre hábitats (T=-1,994, P=0,04 MRPP) y estuvo asociada a la cantidad de agua y de materia orgánica acumulada. El índice de diversidad de Shannon de las plantas de sombra es de 2,67 y el de sol es de 1,68.

PRESENCIA DE MICORRIZAS ASOCIADAS A BROMELIÁCEAS DEL SOTOBOSQUE DEL CHACO SANTAFESINO [Mycorrhizae associated to Bromeliaceae species from the understory of a Santafesinian Chaco forest]

Feldman, S.R.[(1,2)]; Cabello, M.[(3)]; Patrignani, A.[(1)] & Barberis, I.[(4)]
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En el sotobosque del chaco santafecino se observan densas colonias de bromeliáceas, tales como *Bromelia serra* (terrestre, con raíces absorbentes arraigadas) y *Aechmea distichantha* (terrestre o epífita facultativa, con raíces para apoyo mecánico o condicionalmente absorbentes). En el marco de un proyecto sobre el rol de las bromeliáceas en la regeneración del bosque chaqueño, el objeto de este trabajo fue constatar la presencia de esporas e hifas de hongos micorríticos en rizosfera y raíces de *B. serra* y *A. distichantha*. Las esporas se separaron mediante filtración y posterior centrifugación en gradiente de sacarosa y las raíces se tiñeron con azul de tripano. Los preparados se montaron en alcohol polivinílico. La riqueza específica de Glomeromycota hallados en la rizosfera de ambas especies es baja, principalmente pertenecientes a los géneros *Glomus* (i.e: *G. clarum*) y *Acaulospora* (i.e. *A. aff. delicata*). Se observó la presencia de hifas vesículo-arbusculares asociadas a las raíces de ambas especies.

DIFERENCIAS EN LA MORFOLOGÍA DE PLANTAS DE *Aechmea distichantha* CRECIDAS AL SOL Y A LA SOMBRA [Morphological differences in *Aechmea distichantha* plants grown in the sun and in the shade]

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En los quebrachales de *Schinopsis balansae* Engl. del Chaco santafesino crece *Aechmea distichantha* Lem. Los individuos de esta epífita facultativa desarrollan tanto al sol como a la sombra del sotobosque, pero presentan diferentes morfologías. El objetivo del presente trabajo fue caracterizar las diferencias morfológicas de individuos que crecen en ambos ambientes. En un quebrachal cercano a Las Gamas, Departamento Vera, Santa Fe, se seleccionaron 8 individuos de sol y 7 de sombra, de tamaño medio a grande. Para cada individuo se caracterizó la morfología general (altura, diámetro promedio, área proyectada y volumen máximo retenido), y la morfología de las hojas (largo, ancho, acanalamiento, ángulos, área, e índice de suculencia) en tres posiciones de la planta (basal, central, apical). Las variables fueron analizadas mediante modelos lineales generalizados y métodos multivariados (PCA y MRPP). Las plantas de sombra poseen mayor altura, diámetro promedio y área proyectada, así como hojas más largas, de mayor área y más acanaladas. En cambio las plantas de sol retienen un mayor volumen de agua y poseen hojas más erectas y suculentas. Estas características influirían en la captación y acumulación de agua, y podrían ser resultado del desarrollo bajo distintas intensidades de luz (plasticidad fenotípica).

EL ESPINAL PERIESTÉPICO: ¿DESAPARICIÓN, PERMANENCIA O TRANSFORMACIÓN DE UNA UNIDAD FITOGEOGRÁFICA? [The Espinal Periestépico: ¿disappearance, permanence or transformation of a phytogeographical unit?]

Barberis, I.M.(1,3); Prado, D.E.(2,3) & Lewis, J.P.(1,3)
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Antes de la conquista del hombre blanco, alrededor de toda la estepa pampeana existían importantes bosques de leñosas espinosas, fundamentalmente de los géneros *Prosopis* y *Acacia*. Cabrera, en su reseña fitogeográfica de la Argentina, incluyó esta área como ‘Provincia del Espinal’, dentro del Dominio Chaqueño. El verdadero estatus fitogeográfico del Espinal es difícil de establecer ya que tiene muy pocos endemismos y puede ser considerado como un ecotono entre las provincias fitogeográficas de la Estepa Pampeana, el Chaco y el Monte Occidental. En la presente contribución se analizan las transformaciones a las que están expuestos los remanentes de bosques de los sectores centrales del Espinal y se discute la importancia de estos procesos sobre la entidad del Espinal como unidad fitogeográfica.

FENOLOGÍA FOLIAR DE ESPECIES LEÑOSAS DE UN QUEBRACHAL DE LA CUÑA BOSCOSA SANTAFESINA.
[Foliar phenology of woody species of a quebrachal forest in the Cuña Boscosa Santafesina]

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El objeto de este trabajo es caracterizar la fenología vegetativa de especies leñosas del quebrachal de *Schinopsis balansae* Engl., uno de los bosques emblemáticos del Chaco. El clima de la región es subtropical con una estación seca invernal de duración variable con ocurrencia de heladas. En los bosques tropicales lluviosos donde no existe una marcada estacionalidad térmica, las diferencias fenológicas se verifican entre individuos, mientras que en los bosques templados la marcada estacionalidad determina que la variación fenológica entre individuos sea mínima. El quebrachal de la Cuña Boscosa se encuentra en una situación intermedia debido a su ubicación latitudinal. En consecuencia, se evaluó cómo varía la producción de hojas entre años y entre individuos en un período de 3 años. En un quebrachal ubicado en el Centro Operativo Dr Tito Livio Coppa del MAGIC, en Las Gamas, Dpto. Vera, Santa Fe, se seleccionaron especies arbóreas (*Acacia praecox* Griseb., *Aspidosperma quebracho-blanco* Schltdl., *Geoffroea decorticans* (Gillies ex Hook. & Arn.) Burkart, *Myrcianthes cisplatensis* (Cambess.) O. Berg., *Prosopis* spp., *S. balansae* y *Sideroxylon obtusifolium* (Roem. & Schult.) T.D. Penn.) y arbustivas (*Achatocarpus praecox* Griseb., *Capparis retusa* Griseb., *Celtis pallida* Torr., *Maytenus vitis-idaea* Griseb. y *Schinus fasciculata* (Griseb.) I.M. Johnst.). De cada especie se escogieron 10 individuos adultos que fueron mapeados e identificados. La fenología foliar fue registrada mensualmente desde septiembre de 1992 hasta agosto de 1997. Para cada individuo se registró el porcentaje de hojas observadas en cinco fenofases de acuerdo al desarrollo foliar y la cantidad de hojas y se estimó el porcentaje de hojas presentes. Para cada especie se construyeron dos curvas de porcentaje de hojas a lo largo del año, una para mostrar las variaciones entre individuos y otra para las variaciones entre años. Esta comunidad presenta variaciones en la presencia de hojas a lo largo del año. Se observa un mínimo en invierno debido a las bajas temperaturas. De acuerdo a la fenología foliar se distingue un grupo de especies que no pierden sus hojas a lo largo del año (*A. quebracho-blanco*, *M. vitis-idaea*, *M. cisplatensis*, *S. fasciculata* y *C. retusa*), y otro grupo constituído por el resto de las especies, que en invierno pierden o reducen marcadamente la cantidad de hojas. Para todas las especies se registraron amplias variaciones en la fenología foliar entre años, observándose tanto diferencias en el máximo de foliación, como en el momento en que éste ocurrió. Si bien para algunas especies se registraron variaciones entre individuos, éstas fueron menores que las variaciones entre años.

VARIACIONES ESTACIONALES E INTERANUALES EN LA ABUNDANCIA Y COMPOSICIÓN DE AVES ACUÁTICAS EN LA LAGUNA MELINCUÉ, ARGENTINA. [Seasonal and interannual variations in the abundance and species composition of waterfowl in laguna Melincué, Argentina]

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En la planicie pampeana de Argentina (una de las regiones más artificializadas del globo), los humedales representan ambientes altamente complejos distribuidos en un mosaico de ambientes fuertemente simplificados como son los agroecosistemas. Como consecuencia, estos humedales constituyen sitios de concentración de numerosas especies de aves.

Las comunidades de aves acuáticas experimentan fluctuaciones estacionales y anuales en su abundancia y composición específica a escala local y regional. La abundancia de aves a escala local depende de las características del hábitat (tamaño y profundidad del cuerpo de agua y condiciones físico-químicas del agua), disponibilidad, distribución y densidad de alimento, así como la disponibilidad de sitios adecuados para reproducción o descanso. Variaciones en las condiciones del hábitat pueden también producir cambios en la composición específica de la comunidad.

La laguna Melincué (33°25'S, 61°28'O; 84 m s.n.m.), con sus más de 120 km^2 de superficie es uno de los principales sitios de concentración de aves acuáticas en la Pampa Húmeda. En los últimos 20 años registró 2 ciclos húmedos y 2 secos provocando variaciones en la cota que determinaron fluctuaciones en las áreas inundadas de entre 4 y 5 mil hectáreas (aproximadamente 36% del área del humedal). Antes del comienzo de los censos en 1991 no existían estudios sistemáticos sobre la comunidad de aves acuáticas.

Los objetivos de este estudio fueron: a) evaluar las variaciones anuales y estacionales en la abundancia y composición específica de la comunidad de aves acuáticas, y b) evaluar la relación entre estas variaciones observadas y las fluctuaciones en el nivel de las aguas.

Realizamos 14 censos de aves acuáticas desde 1992 hasta 2002 (7 en invierno y 7 en verano). En cada censo se contaron e identificaron al nivel de especie todas las aves presentes en 3 transectas. Éstas comprendían diferentes ambientes: a) Pastizales secos (incluyendo campos agrícolo-ganaderos), b) Aguas poco profundas (incluyendo pastizales inundados), c) Playas barrosas (con y sin vegetación), y d) Aguas abiertas. Se estableció una distancia máxima de observación de 500 m desde la línea central de cada transecta. Las transectas diferían en longitud (rango 8,00 – 11,25 km) y complejidad (diversidad ambiental).

Las especies fueron agrupadas en 5 grupos tróficos de acuerdo a los ítems consumidos: P = plantas (i.e. plantas y semillas), F = Plancton (Filtradores; este grupo comprende a los flamencos - *Phoenicopterus* spp.- y las espátulas - *Ajaia ajaja*), V = vertebrados (e.g. peces, batracios, reptiles, aves, roedores), O = omnívoros, e I = invertebrados (e.g. insectos, moluscos y crustáceos). Dentro del último grupo trófico distinguimos las especies limícolas (I-S), de aquellas aves que obtienen el alimento de otros ambientes (I-O).

Las diferencias estacionales en el número de individuos/km fueron analizadas con Modelos Lineales Generalizados usando la longitud de las transectas como covariable. Las diferencias estacionales en la riqueza específica fueron comparadas usando curvas de rarefacción y las diferencias en la composición de especies entre estaciones fueron evaluadas con métodos multivariados de permutaciones múltiples (MRPP). La asociación de las especies con los censos de invierno o verano fue evaluada con el Análisis del Valor Indicador de las Especies.

Para cada estación, se realizaron pruebas de correlación para evaluar la asociación entre la abundancia de aves, la riqueza y diversidad de especies con la cota de la laguna. A su vez, para cada estación se realizó un análisis de correspondencia (CA) para evaluar si la composición de especies estaba asociada con la cota de la laguna o con la ubicación de las transectas. Las diferencias entre grupos tróficos respecto a su ubicación a lo largo de los dos primeros ejes del CA fueron evaluadas con la prueba Kruskal-Wallis. Los análisis multivariados se realizaron con el programa PC-ORD.

Detectamos 223.643 individuos pertenecientes a 71 especies de 17 familias. Las especies más abundantes fueron *Fulica leucoptera*, *Larus maculipennis*, *Phoenicopterus chilensis*, *Plegadis chihi*, *Anas platalea*, *Himantopus mexicanus* y *Rollandia rolland*. La abundancia de aves fue similar en invierno (promedio ± s.e.m. = 522 ± 74) y verano (promedio ± s.e.m. = 522 ± 74) ($\chi 2$ 1 g.l. = 1,02, P = 0,31), pero la riqueza y la composición de especies difirieron entre estaciones (prueba MRPP: T = -2,64, P = 0,012). Registramos 65 especies en verano y 59 en invierno. *Phoenicopterus chilensis* y *Anas sibilatrix* estuvieron casi restringidas al invierno, mientras que *Ajaia ajaja*, *Phalacrocorax olivaceus*, *Ardea ibis*, *Sterna nilotica*, *Egretta thula*, *Mycteria americana*, *Charadrius collaris*, *Anas versicolor*, *Calidris fuscicollis* y *Ciconia maguari* fueron casi exclusivas del verano (Test Monte Carlo del Valor Indicador de las Especies P < 0,05).

A lo largo del período de estudio, la cota de la laguna fluctuó 1,64 m (entre 83,62 y 85,26 m s.n.m.). La abundancia de aves en cada censo estuvo positivamente asociada con el nivel de la laguna (r = 0,62, P = 0,018). En los censos de verano, la mayor variación en la composición de especies a lo largo de los años (Eje I CA, valor Eigen = 0,405) estuvo asociada con las fluctuaciones en la cota (r = -0,63, P = 0,003), mientras que el segundo eje (valor Eigen = 0,253) discriminó a los censos según las transectas. El primer eje discriminó a las especies según los grupos tróficos (H = 24,18, 6 g.l., P < 0,001). Las especies limícolas (*Limosa haemastica*, *Micropalama himantopus*, *Charadrius collaris*, *Tringa flavipes*, *Tringa solitaria*, *Calidris canutus*, *Calidris bairdii* y *Calidris melanotos*) y las omnívoras (principalmente *Larus cirrocephalus* y *Larus maculipennis*) predominaron en aquellos años de cota baja, mientras que las especies que se alimentan principalmente de plantas (*Amazonetta brasiliensis*, *Anas bahamensis*, *Coscoroba coscoroba*, *Cygnus melanocorypha*, *Dendrocygna bicolor*, *Fulica rufifrons*, *Fulica leucoptera* y *Netta peposaca*) o vertebrados (*Phalacrocorax olivaceous*, *Podiceps major*, *Rollandia rollands*, *Podilymbus podiceps*, *Mycteria americana*, *Nycticorax nycticorax*, *Ardea alba*, *Ciconia maguari* y *Egretta thula*) predominaron en aquellos años de cotas altas. Aquellas especies que se alimentan de invertebrados (no limícolas) (*Ardea ibis*, *Himantopus mexicanus*, *Phimosus infuscatus*, *Plegadis chihi* y *Vanellus chilensis*) y aquellos que se alimentan de invertebrados y plantas (*Anas flavirostris*, *Anas georgica*, *Anas platalea*, *Anas versicolor*, *Dendrocygna viduata* y *Heteronetta atricapilla*) predominaron en años con cotas intermedias.

Variaciones extremas en las condiciones ambientales son eventos relativamente comunes en lagos salinos. La dinámica de estos sistemas es controlada por fluctuaciones a escalas temporales que varían de varios años a décadas (ENSO). Estudios de corto plazo que no tienen en cuenta la particular dinámica de estos sistemas pueden conducir a generalizaciones erróneas, con el correspondiente impacto en el manejo y conservación. A lo largo del período de estudio, la laguna Melincué experimentó importantes modificaciones en sus condiciones físicas. El registro de datos por un período relativamente largo (10 años) provee una excelente oportunidad para detectar el efecto que estos cambios de mediano a largo plazo tienen sobre la comunidad de aves acuáticas. Por lo tanto, la información generada en este estudio podría ser de gran utilidad a la hora de elaborar planes de manejo y conservación de las especies en particular y del sistema en general.

Desde el punto de vista de la conservación, este humedal reúne tres de los criterios de la convención RAMSAR. Melincué es uno de los dos humedales de llanura en Argentina que sustenta grandes poblaciones de *Phoenicopterus andinus* en su área de distribución invernal. Esta especie es clasificada como vulnerable por la IUCN, lo que avala la inclusión del humedal bajo el 2do criterio RAMSAR. A su vez, éste humedal alberga en invierno entre el 5 y el 7% de la población mundial estimada para esta especie, justificando su inclusión bajo el 6to criterio RAMSAR. Finalmente, los resultados de los Censos Neotropicales de Aves Acuáticas demuestran que Melincué alberga regularmente más de 20.000 aves acuáticas, justificando su inclusión bajo el 5to criterio RAMSAR.

Si bien este humedal está categorizado como Reserva Provincial de Usos Múltiples, carece de efectiva implementación, por lo cual su conservación enfrenta serios riesgos potenciales. Sería altamente recomendable el desarrollo e implementación de un plan estratégico de manejo que asegure su efectiva conservación a futuro.

VI. APPENDIX

VI.1. EXPENDITURES

Expenditures	**Pounds**
Plot set up (iron marks, subplot labels, etc.)	112.10
Travel costs (petrol)	353.48
Food and accommodation	527.50
Computer supplies (toner, cds, etc.)	52.15
Thetaprobe ML2 (Thetakit v3)	1656.58
SkyWatch Geos (Pocket Weather Monitor)	144.65
LI-190SA Quantum sensor	482.10
Total	**3328.56**

In this short expenditures report we show what the funds were spent on. As we explained in the Difficulties section of this report, the cost of the Thetaprobe ML2 (Thetakit v3) was higher than expected in our proposal because of the modification of the exchange rate between GB Pound and Argentinean Pesos and the running year inflation.

We still have some remaining money (GBP 672.0) for fencing of cattle exclosures and bromeliad removal. This work was delayed due to climatic conditions (See Difficulties section). As the prices for poles, wires, etc. have been agreed with the sellers, we think that the money provided by RSG will be enough for finishing the setting up of the experiment. We will receive some money from CONICET only for a couple of field trips (i.e. fuel and accomodation).

The money provided by RSG would be enough for setting up the experiment, but we are applying to an additional grant (RSG Continuation) in order to continue the surveys for the diversity studies.