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POLLEN DEPOSITION IN TAUBER TRAPS AND SURFACE SOIL SAMPLES IN THE MAR CHIQUITA COASTAL LAGOON AREA, PAMPA GRASSLANDS (ARGENTINA)

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Summary: Pollen deposition in Taubertraps and surface soil samples in the Mar Chiquita coastal lagoon area, pampa grasslands (Argentina).
Estimations of airborne pollen loadings deposited in Tauber traps were studied in a coastal lagoon from south-eastern Pampa grasslands, Argentina, in order to assess their relationship with surface samples and to interpret the representativeness of local, regional and extraregional vegetation. Three different environments were considered: a coastal dune barrier with a psammophytic community, a salt marsh with a halophytic community in Mar Chiquita lagoon, and a freshwater community at Hinojales freshwater lake. Based on a record of surface samples taken from a previous paper, a parametric model was built to classify Tauber samples gathered from the natural vegetation communities of the study area. Results revealed that just like their surface counterparts, Tauber trap records qualitatively reflect the predominant vegetation types, although ecological groups feature different quantitative representations depending on the record type. Pollen loadings showed that airborne pollen transport was predominantly of local range, in accordance with previous results from the same study area. Airborne – surface samples relationships enrich our knowledge of the present environment that could be useful to improve paleoecological interpretations of the area.

Key words: Modern pollen deposition - Discriminant analysis - Spatio-temporal scales.

Resumen: Depósito polínico en trampas Tauber y muestras de superficie en el área de la laguna costera de Mar Chiquita, pastizales pampeanos (Argentina).
Se estimó el depósito polínico atmosférico de trampas Tauber en una laguna costera del sudeste de la estepa pampeana argentina, con el objetivo de analizar su relación con muestras de polen superficial e interpretar la representatividad de la vegetación local, regional y extraregional. Se consideraron tres ambientes diferentes: una barrera costera de dunas con vegetación psamofítica, la marisma de la laguna costera Mar Chiquita, con vegetación halofítica, y la laguna continental Hinojales, con vegetación hidrofítica. En base a las muestras de superficie y análisis de un trabajo previo, se construyó un modelo paramétrico para clasificar las muestras Tauber tomadas en la vegetación natural del área de estudio. Los resultados revelan que como su contraparte en suelo superficial, los registros polínicos Tauber reflejan cualitativamente los tipos de vegetación predominante, aunque los tipos ecológicos difieren cuantitativamente su representación, según el tipo de registro observado. Los datos de polen muestran que el transporte atmosférico de polen es predominantemente local, de acuerdo con resultados previos en la misma área. Las relaciones entre muestras aéreas y de superficie enriquecen nuestro conocimiento del ambiente actual el cual puede ser útil para mejorar las interpretaciones paleoecológicas en el área.

Palabras clave: Depósito polen actual - Análisis discriminante - Escalas espacio-temporales.

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INTRODUCTION

When it comes to answering significant questions about ecological changes from the past, interpreting fossil records is crucial. Presently to attain such reconstruction, methods require refined knowledge of the relationships between patterns and processes, which can only be acquired from modern pollen-vegetation analyses at different spatio-temporal scales. Nevertheless, it is known that surface samples may contain several years of pollen accumulation, able to mask seasonal and annual variation. However, experiments have not been able to determine the number of years represented by such pollen content.

Tauber traps have been used in North America and Europe to characterize daily, seasonal and annual pollen dispersal and deposition from grasslands to forests (Tauber, 1977; Markgraf, 1980; Hall, 1990). Moreover, the need of such information has promoted the development of the Pollen Monitoring Program in a clear attempt to refine and standardize techniques to get comparable results of yearly pollen deposition (Hicks *et al*., 1996, 2001). Studies of such nature are still scarce in South America. In Argentina, available examples are the use of Tauber traps for the construction of pollen calendars of urban or natural areas in different environments (Cuadrado, 1978, 1979; Borromei & Quattrocchio, 1990; García de Albano, 1991; Majas & Romero, 1992; Naab, 1999; Latorre & Caccavari, 2006). Some of them rely on the calibration of the pollen-vegetation relationships on coastal areas (Fontana *et al*., 2001; Fontana, 2003; Pérez *et al*., 2009), becoming great contributors to the environmental reconstruction of the Holocene sea level fluctuations (e.g. Stutz *et al*., 2006; Vilanova *et al*., 2006). For instance, Stutz & Prieto (2003) found similarities between modern pollen spectra of soil samples from different environments in Mar Chiquita coastal lagoon area (Pampa grasslands, Argentina) and fossil pollen assemblages from a core obtained nearby, which allowed interpreting the area vegetation history. Subsequent vegetation and deposition relationships analyzed using Tauber traps enabled to recognize the contribution of local, regional and extraregional sources as well as the role that seasonal phenology, transport and re-deposition play as significant processes, thereby providing additional information to such interpretation (Pérez *et al*., 2009). Nevertheless, the progressive development of pollen analysis is also dependent on advancing our understanding of the way in which pollen reaches and incorporates into the sediment. An area of focus in this paper is the distinctive features of the relationship between airborne, soil samples and the vegetation from Mar Chiquita coastal lagoon area. Its ultimate aim is to enrich paleoecological interpretation by seeking an enhanced understanding of the present environment in the southeastern coast of the Pampa grasslands.

Geomorphology, climate and vegetation of the study area

Mar Chiquita coastal lagoon (37º43'S; 57º24'W) and Hinojales freshwater shallow lake (37º34'S, 57º27'W) are located in the SE of Pampa grasslands (Buenos Aires Province, Argentina) (Fig. 1-2). The area features a smooth topography of different geomorphologic origin, which comprises late Pleistocene deflation basins and paleodunes, and Holocene deposition landforms originated during the last sea level fluctuations, ca. 6000 years BP (Schnack *et al*., 1982; Fasano, 1991; Violante, 1992). From the Atlantic Ocean to inland, three main landforms are recognized: the coastal barrier of sandy dunes and adjacent beaches, the marginal flats whose Holocene deposition process gives rise to the Mar Chiquita coastal lagoon and associated salt marsh, and the Pampa plain with numerous deflation basins, occupied by freshwater bodies like Hinojales lagoon, and associated paleodunes (Stutz & Prieto, 2003).

The climate is temperate with annual mean temperature and precipitation of 13.8ºC and 940.6 mm respectively (Mar del Plata Aero-meteorological station, 37º33.6'S, 57º21'W, Servicio Meteorológico Nacional, unpublished). Mean temperature varies from 20ºC in January to 7.3ºC in July. Rainfall occurs mainly from spring to autumn, with a maximum of 112.3 mm in February and a minimum of 45.3 mm in August. During summer, winds are typically from the N, NE and E turning to NW to SW in winter.

Several authors have described and classified the vegetation of the area (Vervoorst, 1967; Cabrera, 1976; León, 1991; Stutz, 2001; Federman, 2003). In the early 20th century, natural vegetation was significantly affected by human settlements, being displaced by agriculture and cattle breeding and by their attendant flora of weeds. Natural vegetation persists in freshwater shallow lakes, in marginal salty flat, and in the coastal barrier of sandy dunes where soils cannot be cultivated. Freshwater lake communities are characterized by emergent, floating-leaf and submerged macrophytes. The dominant species is *Schoenoplectus californicus* (C.A. Mey.), which grows in a patchy distribution towards the lake centre. Other emergents like *Zizaniopsis bonariensis* (Balansse and Poitr.), *Hydrocotyle bonariensis* Lam., *H. ranunculoides* L.f., *Alternanthera philloxeroides* (Mart.) Griseb. f. philoxeroides, *Buddlegia elegans* Cham. & Schltdl. ssp. elegans, *Solanum glaucophyllum* Desf., *Bacopa monnieri* (L.) Pennell, *Polygonum punctatum* Elliott, and *Ranunculus apiifolius* Pers. grow interspersed within *Schoenoplectus* patches in the shallowest zones. Near the shore, *Ricciocarpus natans* (L.), *Azolla filiculoides* Lam., *Lemna valdiviana* Phil., and *Wolffiella lingulata* (Hegelm.) Hegelm. form a dense carpet. *Myrioplyllun elatinoides* Gaudich. and *Ceratophyllum demersum* L. develop not only in the deepest parts but also in the shore where no other vegetation exists (S. Stutz & M. González-Sagrario, personal observations). On silty dunes surrounding the lakes, monospecific woodlands of *Celtis tala* L. constitute the only native arboreal vegetation. On the marginal flat, surrounding Mar Chiquita lagoon, the halophytes *Spartina densiflora* Brong. and *Sarcocornia perennis* (Mill.) A.J.Scott, are the main components of an extended halophytic community. Surrounding this zone, *Distichlis scoparia* (Kunth) and *D. spicata* (L.) co-dominate, accompanied by *Atriplex montevidensis* Spreng., *Spartina alterniflora*, *Grindelia discoidea* Hook. & Arn., and *Limonium brasiliense* (Boiss.) Kuntze, among the most important species. In the highest zone, patches of *Juncus acutus* Guss. also occur with *Ambrosia tenuifolia* Spreng., *Paspalum vaginatum* Sw., *Hydrocotyle bonariensis*, *Scirpus cernuus* Vahl., *Apium sellowianum* H. Wolff and *Samolus valerandi* L.. The coastal barrier is mainly distinguished by psammophytic open vegetation composed of Poaceae, Cyperaceae, and Asteraceae species. Patches of *Spartina coarctata* Trin. with *Calycera crassifolia* (Miers) Hicken, *Senecio crassiflorus* (Poir.) DC. var. crassiflorus and *Cakile maritima* Scop., as associated species, characterize recently formed dunes facing the beach. Mobile dunes exhibit patches of the pioneer grass *Panicum racemosum* (P. Beauv.) Spreng. while further inland, on fixed dunes, *Adesmia incana* Vogel var. incana and *Poa lanuginosa* Poir. dominate, accompanied by *Poa barrosiana* Parodi, *Hydrocotyle bonariensis*, *Margyricarpus pinnatus* (Lam.) Kuntze, *Solidago chilensis* Meyen var. chilensis, *Oenothera mollissima* L., *Polygala cyparissias* A. St.-Hil. & Moq., *Senecio crassiflorus*, *Ambrosia tenuifolia*, *Baccharis juncea* (Lehm.) Desf., *B. Microcephala* (Less.) DC., *Gnaphalium cheiranthifolium* Lam., *Daucus montevidensis* Link ex Spreng., *Androtrichium tryginum* (Spreng.) H. Pfeiff., and the adventitious *Centaurium pulchellum* (Sw.) Druce, *Blackstonia perfoliata* (L.) Huds., *Medicago lupulina* L., *Melilotus indicus* (L.) All. and *M.* albus Desr. On slightly humid soils *Androtrichium tryginum* and *Tessaria absinthioides* (Hook. & Arn.) DC. are dominant, frequently associated with *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. which forms almost mono-specific populations. Inter-dune depressions present a coarser vegetation cover, often linked to high water tables quite similar to the freshwater lake communities described above, though with less species. Their main constituents are: *Typha angustifolia* L., *T. latifolia* L., *Schoenoplectus californicus* (C.A. Mey.), *Scirpus maritimus* L., *Carex extensa* Gooden. var. *vixdentata* Kük., *Eleocharis montevidensis* Kunth and several species of *Juncus*. Exotic trees (*Pinus*, *Cedrus*, *Cupressus*, *Eucalyptus*, *Populus*, and *Acacia*) were introduced in the area at the beginning of the 20th century in public parks and gardens. On the coastal barrier, plantations of *Pinus*, *Eucalyptus* and *Acacia* are common.

MATERIALS AND METHODS

A combination of atmospheric trapping and surface samples was used to investigate the dynamics of pollen deposition in the study area. Exotic trees were excluded in order to centre solely on natural vegetation. Only pollen types found in both records were reported and used for the classification analysis. Pollen sums and percentages were recalculated based on the shared taxa.

Correspondence between pollen assemblages of surface samples with plant communities, established by Stutz & Prieto (2003) (Fig. 3a), were used to build a parametric model, afterwards employed to classify the airborne pollen samples collected from traps at each vegetation sub-area. The selected technique was a stepwise discriminant analysis (McLachlan, 1992), which extracts a subset of variables into a set of functions that provide the best separation of *a priori* established groups. Other authors have successfully applied this statistical technique to similar designs, though to different vegetation types (Xu *et al*., 2009). The statistical method allows the model to be validated by re-classifying the same set of surface samples and by checking its performance against the already known assignment of each sample. Pollen diagrams were created with TGView 2.0.2 (Grimm, 2004).

Tauber samples

Tauber traps (Tauber, 1974) were used to assess pollen loading in each area. The traps were placed at five sites corresponding to the main vegetation communities, i.e., Hinojales (freshwater community), Lagunita and Gallinas (halophytic community), Médanos and CELPA (psammophytic community) (Fig. 2). Sampling was carried out at about 1.5 m above ground level in order to enhance the collection of regional pollen (Hicks & Hyvärinen, 1986) and to avoid surrounding vegetation interference that could result in percentages overestimation. The sampling period ranged from November 1994 to September 1996, when it was interrupted due to logistic problems. Whenever feasible, traps were emptied on a monthly basis so as to avoid trap loss due to vandalism or any other unexpected circumstances that could arise after longer exposure periods. Notwithstanding the precautions taken, several traps were lost as a result of cattle or inhabitants destruction (CELPA: 10/95, 12/95, 1/96; Médanos: 11/95, 12/95, 8/96; Hinojales: 12/94, 11/95, 12/95 and Lagunita: 7/96).

Particulate matter entering the trap orifice was collected in10 ml of fluid comprising 1% phenol in glycerol. Collected residues were processed following standard procedures: sieving through a 250 μ mesh, HF and acetolisis (Faegri & Iversen, 1992). Two *Lycopodium clavatum* tablets were added to each sample before treatment for subsequent calculation of pollen loadings (Stockmarr, 1971). A minimum of 300 grains was counted on each sample. The available literature (Heusser, 1971; Markgraf & D'Antoni, 1978; Erdtman, 1971) and the pollen reference collection of the Laboratory of Palaeoecology and Palynology, Universidad Nacional de Mar del Plata, served to conduct the identification analysis.

Pollen types were grouped into ecological groups in line with Stutz & Prieto (2003). Caryophyllaceae, Rosaceae (eg. *Margyricarpus pinnatus* (Lam.) Kuntze), Rutaceae, *Calycera crassifolia* Hicken, and *Adesmia incana* Vogel were included as psammophytic types whereas, Solanaceae (eg. *Solanum glaucophyllum*Desf.), *Typha*, *Alternanthera philoxeroides*, *Myriophyllum*, *Azolla*, *Triglochin,* and *Ranunculus* were taken as hydrophytic types. Cyperaceae included representatives from the hydrophytic and psammophytic communities such as *S. californicus* and *Androtrichum tryginum* respectively, which could not be unambiguously identified. Therefore, it was excluded from the hydrophytic as well as from the psammophytic pollen type categories. Extraregional types encompassed: *Nothofagus*, *Ephedra,* and *Schinus,* whose main sources are located in the Sub-Antarctic forests and in Monte province, circa 1,100 and 500 km away from the study area (Morello, 1958; Cabrera, 1976). Exotic tree types like *Cupressus*, *Populus*, *Eucalyptus*, *Pinus*, *Ulmus*, *Acacia*, *Fraxinus*, *Morus*, *Tamarix*, *Alnus*, *Quercus*, *Castanea* among others, were reported as "Other trees", and not included in further analyses, while Scrophullariaceae, Monocotyledoneae, Rosaceae, and Lythraceae were added and reported as "Other taxa". The results to be compared with surface data were the percentages of the cumulative sums corresponding to the entire 23-month sampling period, considering only those taxa shared by Tauber and surface records.

Different pollen source areas were termed "local", "extralocal", "regional", and "extraregional", according to Prentice (1985).

Surface samples

Data from 24 surface soil samples published in a previous work (Stutz & Prieto, 2003) were selected from the main plant communities (Fig. 2). The same excluding and joining criteria explained above for airborne samples were used to create synthetic pollen variables (Other taxa, psammophytic, hydrophytic, and extraregional types) in the surface samples subset. Data were expressed as percentages of the shared taxa as detailed earlier. The numbering of surface samples was in accordance with Stutz & Prieto (2003). Samples 17 to 21 from the coastal lagoon were not considered in this work.

Table 1. Summary of discriminant function analysis. Selected variables from 24 surface samples categorized into three groups: Psamophytic, Hidrophytic and Halophytic communities. Wilks' Lambda = 0.2718, approx. F (18, 26) = 7.3167, p < 0.0001.

Variable	Partial Wilks' Lambda	F-remove (2,13)	P-level	Tolerance
Poacaeae	0.838	1.258	0.317	0.071
Cyperaceae	0.840	1.233	0.323	0.093
Chenopodiaceae	0.488	6.803	0.009	0.079
Apiaceae	0.865	1.011	0.391	0.154
Psammophytic types	0.749	2.178	0.153	0.692
Hydrophytic types	0.958	0.285	0.756	0.701
Extraregional types	0.882	0.866	0.444	0.289
Celtis tala	0.717	2.559	0.115	0.264
Ambrosia/Xanthium	0.735	2.338	0.136	0.301

Table 2. Eigenvalues, cumulative proportion of variance and Chi square test (a = 0.05) for the first and second discriminant functions.

Disc. Funct.	Eigenvalue	Cum . Prop.	Wilks' Lambda	Chi - Square	df	p-level
1	15.835	0.930	0.027	61.288	18	0.000
2	1.185	1.000	0.457	13.289	8	0.102

RESULTS

The comparison between surface soil and trap samples indicates that they feature similar compositions. They had fifty one percent of the pollen types in common. Fifteen pollen types were exclusively found in surface samples while 13 were only present in pollen traps, most of them trees. Nonetheless, the shared taxa were the main contributors of both pollen assemblages.

Trap records evidenced great differences in pollen composition among sites, although a few ones that exceeded 50% of the total sum dominated most of the traps. An extreme case is CELPA with a 48% corresponding only to Poaceae, followed by Apiaceae (10%) and Asteroideae (8%). Chenopodiaceae dominates Lagunita and Gallinas with 33 and 30%, respectively. Poaceae and Asteroideae are also important taxa with 24 and 11% at Lagunita, and 14 and 18% at Gallinas. Poaceae, Ambrosia/Xanthium, Cyperaceae, and Asteroideae represent the main taxa detected in the trap at Médanos, with 24, 16, 13, and 14%, respectively. Hinojales greatly differs from the other sites. The contribution of *C. tala*, the unique native arboreal taxon of the area, reaches 18% at this site, followed by Poaceae (19%) and Asteroideae (13%). The contribution of other taxa with 16% of the total sum (Fig. 3b) is also particularly worth of mention.

Classification results

The Stepwise Discriminant analysis included 9 variables and yielded the best separation among the three vegetation categories (Table 1). Partial Wilks'

Table 3. Discriminant loadings and classification functions coefficients.

Variables	Discriminant function 1 loadings	Classification function Psammophitic community group	Classification function Halophitic community group	Classification function Hydrophitic community group
Poacaeae	0.067	5.788	6.674	5.845
Cyperaceae	0.331	5.389	6.205	5.535
Chenopodiaceae	-0.529	5.466	6.998	5.506
Apiaceae	0.137	-8.325	-12.433	-8.239
Psammophytic types	0.106	-0.508	-4.507	-2.061
Hydrophytic types	0.148	9.643	11.118	10.042
Extraregional types	0.006	47.260	62.977	44.388
Celtis tala	0.062	29.779	39.440	27.844
Ambrosia/Xanthium	-0.050	5.688	8.350	5.816
Constant		-228.327	-328.239	-233.232

Lambda clearly demonstrated that the variable that contributes the most to the overall group discrimination is Chenopodiaceae, followed by *C. tala*, *Ambrosia/Xanthium* and Psammophytic types. Ninety three percent of the cumulative proportion of the total variance corresponded to the first discriminant function that accounted for a negative association between Chenopodiaceae and Cyperaceae (Table 2 and 3). The second function positively correlated to Psammophytic types, Apiaceae, Extraregional types and *C. tala,* and negatively to Cyperaceae and Hydrophytic types (Table 3). Nevertheless, statistics confirmed that they make no contribution to group discrimination, as the second function is not significant (Table 2).

Figure 4 summarizes the model application to surface (validation) and airborne samples. Results indicate that 87.5 % of the surface samples were properly re-classified; however, performance differed in each group depending on each variable contribution to the model. Consequently, 100 % of the halophytic community group cases were properly re-classified, while 66.6 % of the psammophytic community group and 85.7 % of the hydrophytic community group were. Miss-classified samples were 1 and 5 from the coastal barrier, assigned to the freshwater community group, and 27 from Hinojales freshwater lake, assigned to the psammophytic community group (Fig. 4).

Considering the airborne samples, Hinojales and Lagunita were assigned to the halophytic community, Médanos and Gallinas to the psammophytic community, and CELPA to the freshwater community (Fig. 4).

DISCUSSION

Generally speaking trap record and surface samples bear similarities, as they share half of their pollen types, which are also those characteristic of the different types of vegetation in the area. The only exceptions are surface and trap samples at Hinojales. Surprisingly, *Celtis* and Cyperaceae, which would be expected to be relevant taxa at Hinojales shallow lake, were not always well represented in both types of records. Trap samples from Hinojales displayed extremely low values of Cyperaceae considering its proximity to extensive patches of *Schoenoplectus*. According to Federman (2003), mean *Schoenoplectus* cover at Hinojales freshwater lake reached 16.9%, while the mean percentage cover of total emergent species amounted to 22.6 %. The low percentages of trap samples could be attributed to the fact that sampling was interrupted before the onset of *Schoenoplectus*

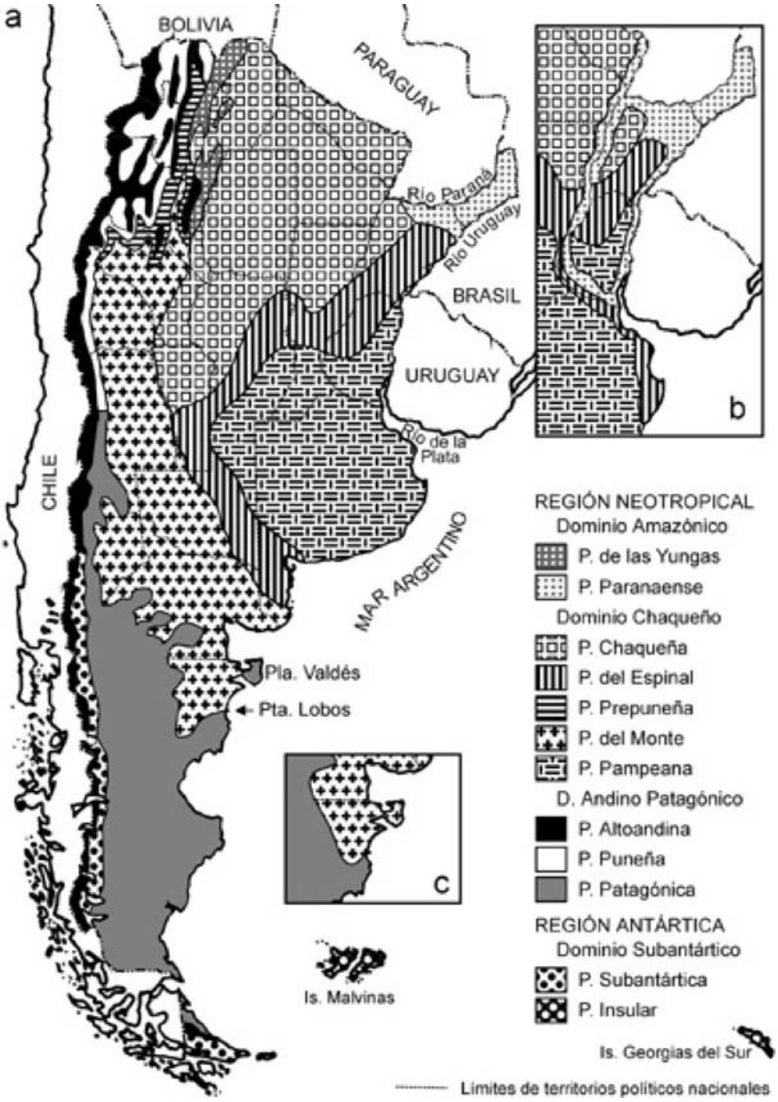

Fig. 1. Phytogeographic classification system of Argentina: a) based on "Regiones fitogeograficas Argentinas" (Cabrera, 1976, 1994), excluding the Argentine Antarctic Sector (Antarctic Province, Antarctic Domain, Antarctic Region); b) northeast fraction based in a previous version (Cabrera, 1958); c) southeast fraction according to Cabrera and Willink (1973, 1980). All maps are accurately recreated from the originals.

flowering during the second year of survey. Being an anemophilous species, *Celtis* also yielded somewhat low percentages maybe due to the trap loss in November 1995, when the maximum *Celtis* air concentration takes place (Latorre, 1999). On the other hand, *Celtis* also exhibits low percentage values in surface samples collected near the lakeshore. As stated by Vilanova *et al*. (2006), *Celtis* woodlands are characterised by surface pollen percentages ranging from 30% in their northern distribution to 70% in the localities closed to the study area. The results obtained cannot be clearly

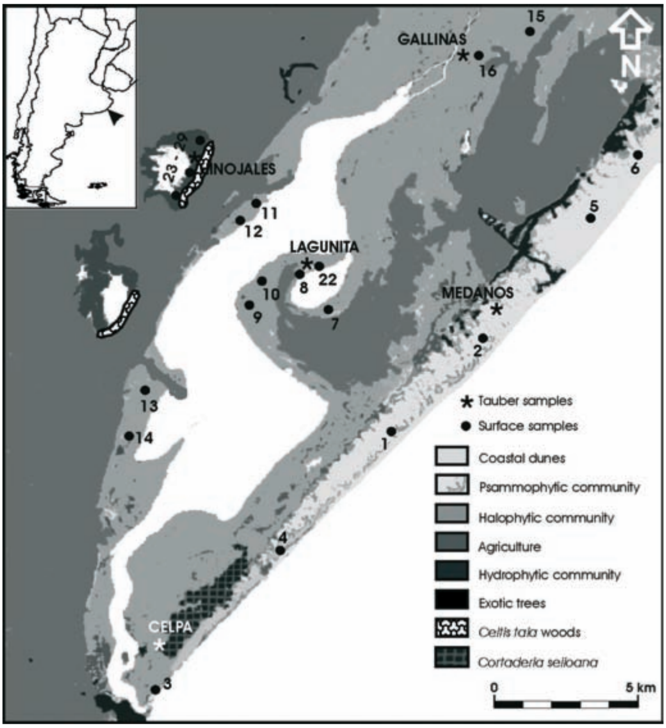

Fig. 2. Vegetation map of the study area and location of surface and Tauber trap samples.

explained, but the perturbed flows induced by the paleodune could play a part. Nevertheless, micrometeorological records from this area should be available to support this hypothesis.

By analysing Tauber samples, it can be ascertained that pollen grains have two distinctive depositional patterns in this complex area, depending on the location of their pollen sources. Scarce inter annual and inter site variation in extraregional pollen loadings lead to infer the existence of a regular contribution from distant sources. Small quantities of pollen types such as *Nothofagus*, *Schinus* and *Ephedra* are present after the dilution of plumes transported over large distances at high altitudes with atmospheric perturbations being unaffected by local circulation (Gassmann & Pérez, 2006). The same hypothesis is held for *Schinus* and *Ephedra* despite the fact that they have been reported closer to the study area like the dune systems at Monte Hermoso, riverbanks of Paraná river, Austral ranges and *Celtis* woodlands of Buenos Aires Province (Vervoorst, 1967; Fontana, 2005; G. Sottile, personal communication). Even so, all these types are not main contributors to the pollen spectra. On the other hand, the other pollen types showed high variability in time and space. In these cases, patterns could be tied to the predominant vegetation composition with minor differences ascribed to the pollination syndrome or to the presence of insect remains inside the traps (Pérez *et al.*, 2009). Therefore, pollen loadings proved that the airborne pollen transport is predominantly local, which is consistent with the results previously described for surface and trap samples (Stutz & Prieto, 2003; Pérez *et al.*, 2009). In some cases, dispersion and transport can be attributed to local circulation systems like the sea-land breeze already described for coastal locations on close localities as already described for Poaceae and *Celtis* (Gassmann *et al.*, 2002; Gassmann & Pérez, 2006).

Discriminant analysis and classification of Tauber trap samples

According to Stutz & Prieto (2003), the psammophytic community is characterized by Poaceae and Cyperaceae presence as well as by

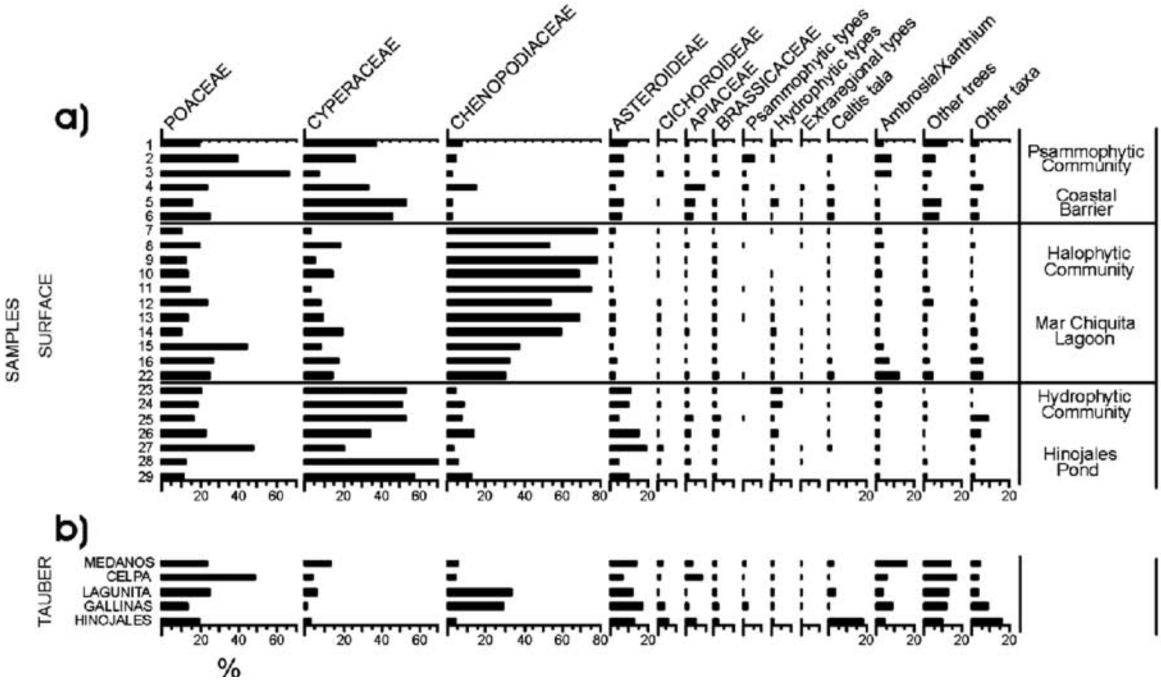

Fig. 3. Surface (a) and Tauber (b) percentages of pollen contribution to each site. Zonation of surface samples was taken from Stutz & Prieto (2003). "Other trees" were excluded for further analysis.

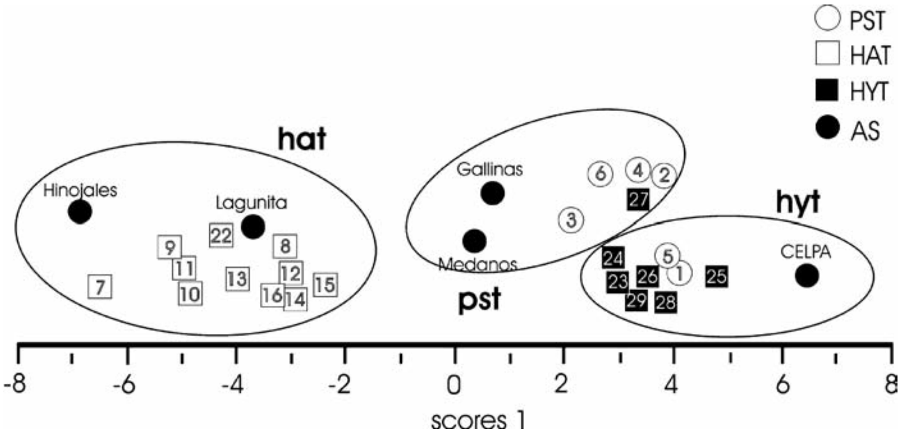

Fig. 4. Calculated scores for the first discriminant function. The dots shapes show the actual group ownership of surface samples. PST: psammophytic community group, HAT: halophytic community group, HYT: hydrophytic community group. AS: corresponds to airborne samples from Tauber traps. Ellipses represent *pos hoc* model assignment of surface and trap samples to halophytic (hat), psammophytic (pst) and hydrophytic (hyt) groups.

psammophytic species. Maximum values of Chenopodiaceae, and the freshwater community, in turn, distinguish the halophytic community, by maximum values of Cyperaceae and hydrophytic types. Chenopodiaceae and Cyperaceae types could be considered the main contributing variables to vegetation communities' distinction. Particularly the first function showed a negative association between Chenopodiaceae and Cyperaceae, thus halophytic community is the best distinguished from hydrophytic and psammophytic groups. Therefore, the model seems to miss-classify surface samples from the psammophytic community, identifying them as those from the freshwater community (associated probabilities of 33.4 and 12.5% respectively). With regard to their pollen assemblages, it is clear that there is a strong resemblance based on their main representatives, Poaceae and Cyperaceae. Morphological reasons led some hydrophytic and psammophytic species such as *S. californicus* and *A. tryginum* (hydrophytic and psammophytic Cyperaceae respectively) or *Hordeum murinum* L. ssp. murinum and *P. racemosum* (hydrophytic and psammophytic Poaceae) to be included in the same taxon, thereby diluting the differences between both communities. Yet there are some representatives present in both communities such as *Schoenoplectus,* growing at Hinojales banks and at the interdune depressions that contribute to the similarities.

The classification of Tauber samples showed that only Lagunita and Médanos were correctly assigned to the vegetation communities. Despite the high percentages of Chenopodiaceae pollen, explained by its location within the salt marsh, Gallinas was possibly assigned to the Psammophytic community given the unexpectedly high values of *Ambrosia* and psammophytic pollen types. The later registered an over-representation of Caryophyllaceae, due to the presence of insect remains in one of the traps (Pérez *et al*., 2009). Despite CELPA being located within the psammophytic vegetation, the classification assigned it to the hydrophytic community. The presence of interdune depressions with abundant *Schenoplectus*, *Carex* and *Eleocharis* (Stutz & Prieto, 2003), and a nearby monospecific stand of *C. dioica*, contributes to high percentages of Cyperaceae and Poaceae, which is also distinctive of the hydrophytic community. Hinojales was assigned to the halophytic community regardless of the very low percentages of Chenopodiaceae and the high values of *C. tala*, Asteroideae and Poaceae. Nevertheless, it seems that this sample is poorly represented by the first discriminant function but best related to the second, which is not statistically significant.

The first discriminant function describes a pattern of vegetation from positive scores for the hydrophytic community to negative ones for the halophytic community with the psammophytic community lying in between. These results seem to represent a gradient of salinity: the more negative the scores the more salty the soils, in agreement with previous results (Stutz & Prieto, 2003). The uneven results derived from the classification of Tauber samples are not clear enough to determine whether trap samples follow this salinity gradient detected in surface samples or not. More research and longer monitoring periods are necessary to be conclusive about a record providing faster responses to weather and phenology rather than to plant populations and vegetation communities.

CONCLUSIONS

The main pollen types at Mar Chiquita costal lagoon area shared by Tauber and surface records which qualitatively reflect the predominant vegetation types. Differences were mainly observed at the hydrophytic community (Hinojales freshwater lake) where *C. tala* and Cyperaceae, the main characteristic types of the local vegetation, were not always well represented on both records. Also, pollen transport was observed on both records as predominantly local.

Most surface samples were properly re-classified after discriminant validation, but classification of Tauber traps yielded regular results in accordance with the particular features of each site. The halophytic community was the easiest to recognize according to the discriminant function that yielded a negative association between Chenopodiaceae and Cyperaceae, probably connected to a salinity gradient. Nevertheless, morphological features did not allow identifying characteristic psammophytic from hydrophytic pollen types which yielded poor classification results for the communities. Further and extensive research efforts would be necessary to raise the level of understanding on the way in which pollen reaches and incorporates in the sediment in this area.

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