Present and Past Coastal Dune Environments of South Buenos Aires Province, Argentina

BY
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**Abstract**


The aim of this thesis is to describe present and past coastal dune environments in southern Buenos Aires Province, Argentina.

The present vegetation of a dune system and its zonation are described on the basis of air photographs, physiognomy of the dune system and floristic composition. The vegetation was characterized by a large number of Poaceae and Asteraceae species. Five vegetation zones, based on floristic composition, were defined by cluster analysis.

Pollen-vegetation comparison revealed that pollen assemblages differed considerably from the associated vegetation. Some of the major discrepancies were caused by large differences between pollen and vegetation proportion of *Hyalis argentea* and *Discaria americana*. However, the local vegetation was well represented in recent soil samples. Pollen traps recorded predominantly extralocal and regional pollen.

A new species of ostracods was recovered from an interdunal lake. The species, a giant cypridid, was described and illustrated, and its geographical distribution and ecology were discussed.

Two sediment sequences from the coastal intertidal zone and from a shallow freshwater lake were analysed for loss on ignition, calcareous microfossils (ostracods and foraminifers), macro remains and pollen. The coastal sequence was deposited between 7890 and 7630 cal. BP. Its pollen assemblages were typical for halophytic associations, with some psammophytic taxa also present in recent vegetation. The microfossils were representative of a littoral lagoon. The lake sequence comprised the last 3000 cal. BP. Pollen spectra indicated a relatively stable vegetation composition after the lake had been formed. Pollen assemblages reflected the present regional grassland vegetation with taxa characteristic for the surrounding dune communities. Human settlement was indicated in the pollen spectra by the presence of introduced taxa in the uppermost samples.

The data presented provide a useful reference for the interpretation of fossil sequences from similar environments.

*Keywords: pollen, ostracods, dune vegetation, Holocene, Buenos Aires Province, Argentina*

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To Leonor and Roberto
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This thesis is based on the following papers, which are referred to in the text by their Roman numerals:


II. Fontana, S.L. Coastal dune vegetation and pollen representation in south Buenos Aires Province, Argentina. *Journal of Biogeography* (Submitted)

III. Fontana, S.L. and Ballent, S. A new giant cypridid ostracod (Crustacea) from southern Buenos Aires Province, Argentina *Hydrobiologia* (Submitted)

IV. Fontana, S.L. Holocene vegetation history and palaeoenvironmental conditions on the temperate Atlantic coast of Argentina, as inferred from multi-proxy lacustrine records. (Manuscript)

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1. Introduction

Coastal sand dunes occur all over the world. They are complex ecosystems with a high internal variation, which is mostly due to their zonation along the coastline (Van der Maarel, 1993). The division of dune systems into zones has worldwide applicability and dune plant communities are often comparable in many regions of the world (Doing, 1985). Coastal sand dunes are also very dynamic ecosystems. Species composition and vegetation cover may change rapidly and drastically, driven by changes of environmental factors influencing dune vegetation (Van der Maarel, 1981).

Sand dunes on the temperate Atlantic coast of South America extend from Brazil, Uruguay to Argentina between 28º to 39º lat. S. The present coastal features were formed during and after the last marine transgression. Pleistocene and Holocene deposits occur within the coastal dunes as barriers, marshes, coastal lagoons, tidal flats and chenier plains.

The reconstruction of Holocene environments is often based on plant and animal remains preserved in sediments. Palaeoenvironments may also be reconstructed based on the physical and chemical characteristics of the sediments. Diverse types of fossils can be found in sediments and used as indicators of past biota. Pollen and spores are most commonly used for the reconstruction of Holocene vegetation history. Seeds, fruits and charophyte oospores are frequently used for palaeoenvironmental reconstructions. Ostracods and foraminifera are widely applied to reconstruct the past history of their aquatic habitats.

In order to interpret these fossil records as objectively as possible, a good understanding of the present day environments is required.

Interpretation of Quaternary pollen assemblages can be improved by a better understanding of the modern pollen-vegetation relationship. Pollen representation is biased by several factors such as differences in pollen production, dispersal and preservation of taxa (Prentice, 1988). Thus, pollen abundance cannot be translated directly into plant abundance in the vegetation when interpreting pollen assemblages from the past.

Modern pollen-vegetation studies in Argentina have been carried out mainly in the Andean Cordillera, Patagonia and Pampa grassland (e.g. Markgraf et al., 1981; Schäbitz, 1989, 1994, 1999; Borromei and Quattrocchio, 1990; Majas and Romero, 1992; Mancini, 1993; Paez et al., 1997, 2001; Prieto, 1992, 1996; Naab, 1999; Heusser, 2000). Although relevant Holocene deposits are present along the coast, little attention has
been paid to coastal sand dune environments (Fontana, 2003; Stutz and Prieto, 2003).

The late Quaternary vegetation history of the region has been inferred mainly from pollen records recovered from outcrop sections along river valleys and from loess sequences (e.g. Prieto and Paez, 1989; Paez and Prieto, 1993; Borromei, 1995, 1998; Quattrocchio et al., 1995, 1998; Prieto, 1996, 2000; Grill, 1997, 2003).

Palynological studies based on lacustrine records for this region are few (e.g. Zavala et al., 1992; Prieto, 1993; Mancini, 1994; Stutz et al., 2002).

Information from microfossil studies in the region originate mostly from coastal environments and fluvial sections (e.g. Whatley and Moguilevsky, 1975; Bertels and Martinez, 1990, 1997; Zavala et al., 1992; Ferrero, 1996; Whatley et al., 1997; Bertels-Psotka and Laprida, 1998a, 1998b, 1998c; Laprida, 1998, 2001).

This thesis focuses on the description of present-day coastal dune environments of south Buenos Aires Province, Argentina as an aid to interpret fossil records. In addition, it contributes to the understanding of Holocene environmental changes of the area.

The aims of the present study are:

- To describe the coastal dune vegetation
- To investigate the pollen-vegetation relationship
- To establish a pollen-vegetation analogue for the coastal dunes
- To study modern ostracod assemblages from interdunal lakes
- To reconstruct the Holocene vegetation and environmental history

In order to achieve these aims the vegetation of the active dunes and its zonation at Monte Hermoso was described. Modern pollen deposition was studied by means of surface soil samples and pollen traps. Surface samples from interdunal lakes in the area of Balneario Sauce Grande were analysed for pollen and ostracods content.

Palaeoenvironmental conditions were reconstructed from two sediment sequences recovered at La Olla 1 site and Laguna del Sauce Grande using pollen, calcareous microfossils (ostracods and foraminifers) and macro remain analysis. Supplementary information was provided by sedimentological analysis. The chronology is based on radiocarbon dating.
2. Study area

Buenos Aires Province is a vast plain with slight undulations. Only a small proportion of the region to the south-east and south-west of the Province comprises mountain relief. The plain ends at the Atlantic in a coastal dune system.

Temperate sub-humid grasslands known as pampas cover the inland region (Cabrera, 1968) and characteristic sand-requiring vegetation grows on the dunes (Cabrera, 1941; Pfadenhauer, 1993). To the south of the study area the ‘pampa’ grassland abuts on the xerophytic forest known as ‘espinal’ (Cabrera, 1968).

The area is characterized by a dry sub-humid climate with mesothermic features and little or no water surplus (Burgos and Vidal, 1951). The mean monthly temperatures vary between 24ºC in January and 8ºC in July. Precipitation is unevenly distributed during the year with maxima in spring and in the end of summer. A period of water deficit occurs in summer. Annual average rainfall is 540 mm. Dominant winds from the north-west are hot and dry in summer and cold and dry in winter.

Local environmental factors make the coastal sand dunes a dry ecosystem (Kumler, 1997). Constant wind, salt spray, sand movement, drought and nutrient deficiency vary greatly within the dune system depending on the topography and the distance to the sea. Therefore, vegetation distribution in the dunes varies according to exposure to these stress factors.

2.1. Sampling sites

Coastal sand dunes

The coastal strip at Monte Hermoso is characterized by flat sand beaches and extended dune systems. Pleistocene-Holocene deposits outcrop at the beach. The dune system extends 4-5 km inland and reaches heights of over 20 m above sea level. It consists of active dunes adjacent to the beach and inactive (fossil) dunes further inland (Fig. 1). Grazing, campgrounds and settlements have disturbed the natural vegetation on these dunes. Even so, it is still possible to find large relicts of nearly natural vegetation.
Temporary interdunal lakes

Diverse temporary fresh water bodies of varying size occur between the inactive (fossil) dunes located in the surrounding area of the Balneario Sauce Grande, about 3 km inland from the present coastline (Fig. 1). They occupy shallow depressions, which are filled with water after rainfall. Some lakes are isolated basins, while others are connected to each other at high water level. Most of these lakes dry out during the summer season.

La Olla 1

La Olla 1 is an archaeological site that contains significant information about the use of marine resources by hunter-gatherers during the early Holocene (Politis and Bayón, 1995; Johnson et al., 2000). It is located in the coastal inter-tidal zone at 38° 60’ S and 61° 21’ W (Fig. 1). The site consists of lacustrine sediments that have been deposited during periods of lower sea level. Today, the site is usually covered by beach sand. It has been exposed only a few times and for brief periods, during exceptionally low tide.

La Olla 1 is spatially and temporally associated with Monte Hermoso I, a site located 200 to 1000 m west (Zavala et al., 1992; Bayón and Politis, 1996). Human footprints together with other prints of birds and an artiodactyl are preserved in the lacustrine sediments of this site.

Laguna del Sauce Grande

Laguna del Sauce Grande is a shallow fresh water lake located 8 m above sea level and approximately 4 km from the Atlantic coast (Fig. 1). It covers an area of 23 km², with mean water depth of 1.1 m. The lake occupies an aeolian depression, receiving waters from the river Sauce Grande. The river originates in the Sierras Australes, a mountain range rising up to 1250 m, located 200 km north of the lake, and enters the Atlantic Ocean about 20 km southeast of the study site. The lake is elongated east-west. A low escarpment characterizes the northern shore, while the southern shore borders the dune system. A narrow shore belt of Schoenoplectus californicus and Typha dominguensis surrounds the lake.
3. Methods

3.1. Sampling techniques

This investigation is based on data collected throughout several field trips to the study area during the period 1995-2002.

Figure 1 (a) Location of the study area. (b) General overview of the coastal strip at Monte Hermoso and Balneario Sauce Grande, showing the location of the sampling sites. (c) Zonation of the active dunes with the location of the sampling plots and pollen traps. The zones are based on the interpretation of air photographs (scale 1:20000) and phytosociological studies of the vegetation.
Vegetation analysis

The vegetation of the active dunes and its zonation was described on the basis of air photographs (scale 1:20,000), physiognomy of the dune system and floristic composition (paper II).

Areas, which represent as wide a variety of the natural dune vegetation as possible, were sampled using replicate stands of $10 \times 10$ m. All the species present in the stands were listed and their cover-abundance values were estimated on the 10-point Domin-Krajina scale (Mueller-Dombois and Ellenberg, 1974). Species richness index ($S$) was calculated as a measure of floristic diversity in each sampling plot. Classification of the vegetation, based on the total floristic data set, was done using StatSoft (Tulsa, USA), with Ward’s clustering technique and Euclidean distance.

Pollen deposition

Modern pollen deposition was studied by means of surface soil and lake samples and pollen traps (paper I, II, IV).

Soil surface samples were collected from each vegetation stand following Adam and Merhinger (1975). Each sample consisted of five sub samples of surface soil, taken randomly within the plot.

Sediment surface samples from the temporary interdunal lakes were collected from the sediment accumulation area of the lakes.

Two Tauber traps (Tauber, 1967, 1974) were placed within different vegetation types (Fig. 1). Trap “A” was located on top of a mobile dune at about 15 metres above sea level. Trap “B” was situated in a semi-fixed dune area next to trap A. Each trap consists of a cylindrical container closed at the top by an aerodynamically shaped collar with a 5-cm diameter opening in the middle (Fig. 2). Pollen deposition was monitored monthly over four years.

Figure 2 Pollen trap.
Ostracod assemblages
Modern ostracod assemblages and accompanying biota were studied from sediment surface samples from interdunal lakes (paper III, IV).

La Olla 1 sequence
A 35-cm long sequence from La Olla 1 site was recovered. Sediments were analyzed for loss on ignition (LOI), calcareous microfossils (ostracods and foraminifers), macro remains and pollen. Samples were taken continuously on the basis of distinct lithostratigraphic features. Sample thickness varies between 0.5 and 1.5 cm. Depths were measured from the top of the sequence.

Laguna del Sauce Grande core
Overlapping sediment cores from Laguna del Sauce Grande were collected in the southeast part of the lake, at 38° 57' S and 61° 22' W (Fig. 1), using a 1 m long Russian sampler, 5 cm in diameter (Jowsey, 1966). The uppermost part of the sequence, containing the sediment-water interface, was recovered with a Willner gravity sampler. Thus, a complete and undisturbed sediment sequence of 289 cm length was obtained. The sediment cores were analyzed for magnetic susceptibility, LOI, pollen, ostracods and macrofossil remains, including mostly oospores of charophytes and seeds. Magnetic susceptibility measurements were made initially on all core segments and provide, together with the lithological descriptions, a means of correlation. All the other analyses were carried out on the same series of cores. Samples had a thickness of 1 cm. Depths were measured from the sediment-water interface. Colours were determined using Munsell soil colour charts.

3.2. Laboratory techniques
Sediment analysis
Magnetic susceptibility was measured using a Bartington Instruments meter with a MS2E1 surface-scanning sensor (Bartington Ltd., UK). The sensor is connected to an automatic core logging system, TAMISCAN-TS1 (http://www.geol.lu.se). Measurements were made at 2 mm interval, to obtain a continuous record. A three term running mean was applied to smooth the data.

Water content and dry density were estimated by oven-drying the samples for 24 h at 105°C. Organic matter and carbonate content of the sediment was then estimated by LOI. Samples were heated in a muffle furnace for 5 h at first, 500°C, and then 950°C. Results are expressed as percentages of weight
loss of the sediment in each step related to the dry weight of the samples before combustion (Heiri et al., 2001).

Calcareous microfossils and accompanying biota
Samples were first sieved through 180 and 63 μm mesh without chemical treatment. Charophyte oospores, seeds, megaspores and Cladocera ephippia were recovered from the 180 μm sieve. The remaining material retained on the sieves was treated with hot dilute hydrogen peroxide, sieved through 180, 150 and 63 μm mesh and dried. Ostracods, foraminifers and gastropods were recovered from these fractions.

Ostracod nomenclature follows Gutentag and Benson (1962), Martens and Behen (1994) and Whatley et al. (1997).

Although, there is a considerable literature on ostracods and foraminifers of Argentina, many species still remain to be described. The identification of recent and fossil micro fauna was therefore often difficult. In order to help overcome this problem a new ostracod species is described and illustrated (paper III).

Pollen analysis
Pollen concentration from sediment samples followed the methods described by Bennett and Willis (2001). Samples from pollen traps were prepared in accordance with standard methods described by Hicks and Hyvärinen (1986) and Hicks et al. (1996).

Lycopodium tablets (Stockmarr, 1971, 1972) were added to enable calculation of pollen concentration and accumulation rates.

Pollen grains and spores were identified with reference to Stix (1960), Heusser (1971), Markgraf and D’Antoni (1978), Hässel de Menéndez (1989, 1990), Moore et al. (1991), Prieto and Quattrocchio (1993), Telleria and Daners (2003). Pollen collections at the Museum of Natural Sciences, University of La Plata, the Department of Biological Sciences, University of Buenos Aires and the Department of Earth Sciences, Uppsala University, were consulted as a reference material.

Palynological richness (\(E(T_n)\)) was estimated by rarefaction analysis (Birks and Line, 1992). The terms “local”, “extra-local”, “regional” and “extra-regional” used in the text refer to different pollen source areas following Prentice (1985).

The term “seed” used for *Ruppia cf. maritima* in this publication refers to the fruiting structure of the plant.

### 3.3. Data analyses

#### Pollen-vegetation relationship

Pollen percentage values from surface soil samples and pollen traps were compared to the surrounding vegetation percentages at each sampling site (paper I, II). Additionally, scatter plots and indices of association, under and over-representation were used to explore the qualitative and quantitative relationship between vegetation and its pollen representation (paper II).

Association (*A*), under-representation (*U*) and over-representation (*O*) indices were calculated in accordance to Davis (1984), using presence-absence data of a plant taxon and its pollen from 100m² plots. The indices were calculated by the following formulae for all taxa found as both plant and pollen in one or more of the stands:

\[
A = \frac{B_0 \times (P_0 + P_1 + B_0)}{P_0 + P_1 + B_0}
\]

\[
U = \frac{P_1 \times (P_1 + B_0)}{P_1 + B_0}
\]

\[
O = \frac{P_0 \times (P_0 + B_0)}{P_0 + B_0}
\]

where \(B_0\) = number of stands where the pollen type is present in the surface sample and the associated plant taxon is present in the vegetation, \(P_0\) = number of stands where the pollen type is present in the surface sample but the associated plant taxon is not present in the vegetation, \(P_1\) = number of stands where the plant taxon is present in the vegetation but the pollen type is not present in the surface sample.

Sediment, microfossil and pollen zones were defined numerically using binary and optimal splitting techniques (Bennett, 1996).

Diagrams, rarefaction, accumulation rates, zonation, PCA and age-depth models were carried out using psimpoll (Bennett, 2003).

#### Chronology

Chronological control of the sediment records was obtained by accelerator mass spectrometry (AMS) by radiocarbon dating at the Tandem Laboratory, Uppsala University (Ua) and at the INSTAAR Laboratory, University of Colorado (NSRL). Radiocarbon dates were calibrated against the IntCal98 calibration curve (Stuiver et al., 1998) using the BCal online system.
(http://bcal.shef.ac.uk). An offset of $23 \pm 4$ $^{14}$C yr, due to natural 19th century Southern Hemispheric $\Delta^{14}$C differences, was applied during the calibration process (Stuiver and Braziunas 1998; Stuiver et al., 1998).

The chronology of La Olla 1 site was based on five radiocarbon dates of macroscopic remains of terrestrial and submerged aquatic plants (Table 1). The variability of $^{14}$C ages suggests a reservoir effect in the aquatic samples within the sedimentary unit. The shift between the aquatic and terrestrial samples was estimated as $783 \pm 55$ $^{14}$C yr by applying a polynomial (two-term) age-depth model (Bennett, 1994) to the aquatic radiocarbon dates of the sequence. Thus, an age for the point at $22.60$ cm depth could be calculated and then subtracted from the terrestrial radiocarbon age at that depth. This offset was applied during the calibration of the samples at La Olla 1 site. In addition, two dates were considered as outliers with prior probabilities of 50% and 100% respectively (Table 1).

Table 1: Radiocarbon dates from La Olla 1 and Laguna del Sauce Grande.
* Absolute modern % (pM). ** 50 % outlier probability. *** 100 % outlier probability.

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>Material analysed</th>
<th>Uncalibrated age (14C yr BP)</th>
<th>Calibrated age weighted average (2\sigma interval)</th>
<th>Δ R</th>
<th>Laboratory nº</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>La Olla 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-1.1</td>
<td>Ruppia cf. maritima seeds</td>
<td>7580±60</td>
<td>7630 (7509-7754) 806±59 NSRL-11044</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5-6.2</td>
<td>Ruppia cf. maritima seeds</td>
<td>7750±60**</td>
<td>7695 (7590-7795) 806±59 NSRL-11045</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.3-8.9</td>
<td>Ruppia cf. maritima seeds</td>
<td>7635±75</td>
<td>7740 (7635-7843) 806±59 Ua-16106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.1-23.1 terrestrial macro remains</td>
<td>7040±55***</td>
<td>7815 (7685-7941) 23±4 NSRL-11046</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.7-34.4</td>
<td>Ruppia cf. maritima seeds</td>
<td>7920±90</td>
<td>7890 (7719-8045) 806±59 NSRL-11047</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Laguna del Sauce Grande</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66-67</td>
<td>Shells of living H. parchappii</td>
<td>105.4±0.4 pM*</td>
<td>550±40 565 (506-644) 23±4 Ua-20985</td>
<td></td>
<td></td>
</tr>
<tr>
<td>123-124</td>
<td>H. parchappii shells</td>
<td>1275±50</td>
<td>1170 (1059-1284) 23±4 Ua-20866</td>
<td></td>
<td></td>
</tr>
<tr>
<td>170.5</td>
<td>H. parchappii shells</td>
<td>1740±35</td>
<td>1625 (1536-1711) 23±4 Ua-20982</td>
<td></td>
<td></td>
</tr>
<tr>
<td>221</td>
<td>H. parchappii shells</td>
<td>2450±65</td>
<td>2490 (2346-2707) 23±4 Ua-20983</td>
<td></td>
<td></td>
</tr>
<tr>
<td>264.5</td>
<td>H. parchappii shells</td>
<td>2600±35</td>
<td>2670 (2496-2774) 23±4 Ua-20984</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Five radiocarbon dates were carried out on shells of *Heleobia parchappii* (d’Orbigny) to establish the chronology of the Laguna del Sauce Grande core (Table 1). In addition, a $^{14}$C age determination was obtained on shells of living specimens of *Heleobia parchappii* to evaluate the reservoir effect of the samples. A polynomial line-fitting (three-term) age-depth model (Bennett, 1994) was applied to reconstruct the chronology in calendar years (Fig. 3). Shells of the modern material gave an absolute modern $^{14}$C age (Table 1), so no correction for old carbon was needed.

Ages are given as calendar years before present (cal. BP) where ‘present’ is defined as A.D. 1950.
Figure 3 Age-depth model for Laguna del Sauce Grande, fitting a three-term polynomial line by singular value decomposition, using calibrated ages. Top sample was assigned to an age of -50±50.
4. Results and discussion

4.1. Coastal dune vegetation (paper II)

The dune system along the coast of Monte Hermoso is a natural ecosystem characterized by high plant species diversity. Zonation pattern and distribution of plant communities are regulated by environmental factors such as sand stability, groundwater table and distance to the sea, as in many other coastal dune areas of the world (e.g. Barbour et al., 1976; Cordazzo and Seeliger, 1993; Costa et al., 1996; De Villiers et al., 1999; Musila et al., 2001). In proximity to the sea only few species are able to tolerate salt spray and sand movement. At more protected sites with stable and moist soil an increased number of species becomes established.

The vegetation of the coastal dunes at Monte Hermoso is characterized by a large number of Poaceae and Asteraceae species. Dominant species, which occur in more than 50% of the relevés, are: *Hyalis argentea*, *Panicum urvilleanum* and *Poa lanuginosa*, present in almost all the vegetation zones, as well as *Solidago chilensis*, *Aira caryophyllea* and *Hydrocotyle bonariensis*.

Zonation of the vegetation

Five vegetation zones, based on the floristic composition, were defined by cluster analysis at 24-linkage distance units (Fig. 4).

**Back shore**

The back shore extends as a narrow strip along the coast. It is permanently affected by sand and salt spray and episodically by southerly storms. Vegetation covers only 2.4% of the surface and the only species growing in this zone is the grass *Spartina coarctata*.

**Mobile dunes**

The ridges of mobile dunes have a west-east orientation and can reach a height of 30 m above sea level. Sand mobility is the dominant factor that determines species composition. This zone is characterized by open vegetation (46.3%) of dune building species. The succulent *Calycera crassifolia* and *Senecio quequensis* are the diagnostic species for this
community. The dominant species are *Panicum urvilleeanum* and the subshrub *Hyalis argentea*, whereas *Poa lanuginosa* and the holoparasite *Prosopanche bonacinae* occur sporadically.

![Dendrogram of the 25 relevés showing the classification into five vegetation types, based on species composition and their quantitative variation (clustered with Ward’s method and Euclidean distance).](image_url)

**Figure 4**

**Slacks**

The slacks, located within the mobile dunes, are small moist and often waterlogged depressions, which experience occasional fresh water inundation. Here a more complete vegetation cover is found (94%). The character species of this community are the grass *Imperata brasiliensis* and the sedge *Schoenoplectus americanus*. Other sedges like *Isolepis cernua* and *Carex vixdentata* are the differential species. Introduced species such as *Melilotus officinalis*, *Centaurium pulchellum* and *Polypogon monspeliensis* are also diagnostic. Poaceae (*Cortaderia selloana*, *Poa lanuginosa*, *Aira caryophyllea*) and Asteraceae (*Solidago chilensis*, *Achyrocline satureioides*, *Tessaria absinthioides*) species together with *Hydrocotyle bonariensis* are dominant. Several Juncaceae and others Cyperaceae species also occur.

**Semi-fixed dunes**

Farther from the shore, vegetation is more capable of containing the sand, covering 79.4% of the ground surface. This zone is located on the windward side of the dune, facing to the west. The vegetation is characterized by the grasses *Schizachyrium spicatum* and *Aristida spegazzini*. *Margyricarpus*
Pinnatus and Gamochaeta coarctata are also diagnostic species for this unit. Frequent Asteraceae found in the semi-fixed dunes are Hyalis argentea, Solidago chilensis, Achyrocline satureioides and Baccharis divaricata. The shrub Discaria americana and the introduced grass Aira caryophyllea are also common. Occasionally Asteraceae such as Thelesperma megapotamicum and Senecio filaginoides together with the shrub Agalinis genistifolia and Oenothera mollissima are found in this community.

Fixed dunes
The fixed dunes further inland are covered by dense vegetation (98.5%). The shrub Discaria americana and the perennial grass Cortaderia selloana are the dominant species. The climber Clematis bonariensis and the shrub Senecio grisebachii together with Ambrosia tenuifolia, Chenopodium chilense, Bromus catharticus and Solanum chenopodioides are some of the diagnostic species growing in this area. Hyalis argentea, Hydrocotyle bonariensis, Tessaria absinthioides among others are also common species for this community. Schinus areira, Ephedra ochreata, Plantago patagonica are less frequent.

4.2. Pollen representation in coastal dunes (paper I, II)
The degree to which each vegetation type is reflected in the pollen assemblages is influenced by several factors. As a measure of floristic diversity, palynological richness is biased by pollen representation, lack of taxonomic precision in pollen identification and interference of the vegetation structure (Odgaard, 1999).

The pollen representation in the coastal dunes at Monte Hermoso is affected by differences in pollen production and dispersal of individual taxa and differential preservation of pollen grains. The lack of taxonomic precision in pollen identification appears to be the major cause for the poor correspondence between species diversity in the vegetation plots and their palynological richness. However, a high level of taxonomic precision is not as easily achieved in dune environments, as in partly wooded or non-arboreal ecosystems (Brayshay et al., 2000; Davies and Fall, 2001). In these environments, the major vegetation taxa (Poaceae, Cyperaceae, Chenopodiaceae and Asteraceae) produce pollen with only slight morphological variation, which frequently only allows an identification to family level or group of genus. Differences in the composition of the pollen spectra may also be influenced by the spatial distribution of the vegetation, the topography of the dune system and wind pattern.
Pollen spectra

At first sight, the pollen spectra from each of the five vegetation types differ (Figs 5 and 6). However, closer examination of individual spectra reveals wide or no variation within the communities. Thus, the PCA biplot (Fig. 7) shows very distinct pollen spectra from sites closer to the sea (back shore, mobile dunes and slacks) and those further inland (semi-fixed and fixed dunes).

Figure 5 Pollen percentage values of selected taxa from surface samples and pollen traps. Samples are plotted by vegetation type along a gradient from the shore inland. Pollen traps are arranged according to their location in the vegetation. Surface sample numbers refer to the relevé numbers on Figs 1 and 3. Trap A represents 3-yr average (1995/98) and trap B 4-yr average (1995/1999). * Taxa recorded only as pollen.
Figure 6 Pollen-vegetation comparison for the different vegetation zones. Values are given as percentage average of five sites for vegetation and surface samples data and three (1995/98) and four (1995/1999) years for pollen trap A and B respectively. Vegetation percentages values are defined as proportion of the total plant cover in the plot. Pollen influx values are shown for comparison.
Spectra from fixed dunes, semi-fixed dunes and pollen traps are clearly distinct in their pollen composition from all other samples.

Semi-fixed-dune pollen spectra differ, showing high *Discaria americana* pollen frequencies and low amounts of pollen from several indicator taxa such as Solanaceae (mainly *Solanum chenopodioides*) and Scrophulariaceae (mainly *Agalinis genistifolia*), which are not recognized by the ordination. Fixed dunes and pollen trap spectra are distinct in their high Asteraceae pollen frequencies and low amounts of Apiaceae, *Clematis bonariensis*, *Schinus* and *Ephedra* pollen. All other samples (back shore, mobile dunes and slacks) are differentiated by their high percentage of Poaceae and Cyperaceae pollen. However, there is no consistent difference in the pollen proportions between samples that would enable separation of these vegetation types.

**Figure 7** PCA biplot of the sample scores of the individual spectra shown in Fig. 5 and the loadings (eigenvectors) for the main pollen types on the first two principal components axes.

**Pollen-vegetation comparison**

Pollen-vegetation comparisons (Fig. 6) reveal that pollen assemblages from the different zones often differ considerably from the associated vegetation composition. Some of the major discrepancies are caused by the large differences in pollen and vegetation proportion of *Hyalis argentea* and *Discaria americana*. In addition, there is a considerable proportion of non-local pollen in every pollen spectrum. Back shore and mobile dune pollen
assemblages have an important proportion of extralocal pollen taxa like Chenopodiaceae and Cyperaceae. Poaceae and Asteraceae are also important non-local pollen contributors in these zones. Although, they are represented in the local vegetation the pollen morphological variation observed exceeds the number of species growing there. Slacks receive significant amount of extra-local Chenopodiaceae pollen. In the semi-fixed dunes high proportions of *Discaria americana* seem to have an extra-local origin, even so the taxa is locally present. Fixed dune pollen assemblages reflect more accurately the local vegetation. *Hyalis argentea* is lacking in the pollen spectra from the semi-fixed and fixed dunes while it is present in the local vegetation.

Neither do pollen spectra correspond to the vegetation composition in the vicinity of the traps. Most obvious is the lack of *Discaria americana* and Chenopodiaceae from the vegetation cover around the traps although both taxa are well-represented in the pollen catch of the traps. At trap A, as in the surface samples from the associate vegetation, the number of Poaceae and Asteraceae pollen types exceeds the number of species in the local vegetation.

The pollen spectrum recorded in the pollen traps reflects mainly the extra-local and regional vegetation, which may be due to the position of the traps in the field (Hicks and Hyvärinen, 1986).

Mean total pollen influx from the individual traps do not differ considerably from one another (Fig. 6). Mean annual pollen influx and percentage values recorded for the major taxa show also only slight differences between the traps with the exception of *Discaria americana* which shows higher annual influx and percentage values in trap A.

**Pollen-vegetation analogue**

Taking in account the above considerations and since average records for these two pollen traps placed in different settings are similar, a pollen analogue for the Monte Hermoso coastal dunes as a whole can be established as follows (Table 2):

> Total pollen influx of 19000±9600 grains cm⁻² year⁻¹.

Poaceae and Asteraceae are the most abundant taxa present with Poaceae represented by 7100±3900 grains cm⁻² year⁻¹ and 39±9% of total pollen and Asteraceae by 5700±3400 grains cm⁻² year⁻¹ and 29±6%.

*Discaria americana*, *Hyalis argentea* and Chenopodiaceae represent important components of the pollen deposition. *Discaria americana* is represented by 1600±2200 grains cm⁻² year⁻¹ and 7±7%, *Hyalis argentea* by 1100±1100 grains cm⁻² year⁻¹, and 6±4%. Chenopodiaceae shows average values of 1300±700 grains cm⁻² year⁻¹ and 7±3%.
Table 2 Pollen analogue for the coastal dune vegetation of southern Buenos Aires Province, Argentina. Values are given as means with one standard deviation and also as ranges over all observed values.

<table>
<thead>
<tr>
<th>Influx (grains cm(^{-2}) year(^{-1}))</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Poaceae</td>
<td>7100±3900</td>
</tr>
<tr>
<td>Asteraceae</td>
<td>5700±3400</td>
</tr>
<tr>
<td><em>Hyalis argentea</em></td>
<td>1100±1100</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>1300±700</td>
</tr>
<tr>
<td><em>Discaria americana</em></td>
<td>1600±700</td>
</tr>
<tr>
<td>Others</td>
<td>2100±1200</td>
</tr>
<tr>
<td>Total pollen</td>
<td>19000±9600</td>
</tr>
</tbody>
</table>

Small pollen percentages of the following taxa are always present in the pollen catch: *Calycera crassifolia*, Onagraceae (mainly *Oenothera mollissima*), *Plantago* (mainly *Plantago patagonica*), Apiaceae (mainly *Hydrocotyle bonariensis*), *Schinus* and *Ephedra*.

A small proportion (0.9%) of the pollen spectrum consists of arboreal taxa like *Nothofagus*, *Alnus*, and *Celtis* with extra-regional origin.

4.3. Ostracod assemblages (paper III)

The need for description of new species of ostracods in the study area became evident during the initial stage of this investigation. Paper III described and illustrated a new giant cypridid ostracod (Crustacea) from Laguna Caliba (Fig. 1). Specimens were raised from dried sediment recovered from a bank of ostracod shells found at the edges of the lake. Deposition of progressively smaller ostracod valves stacked one into another (cup-in-cup structure) is documented. The geographical distribution and ecology of the genus is briefly discussed.

4.4. Fossil record (paper IV)

La Olla 1

Radiometric age determination and subsequent calibration of terrestrial and aquatic macrofossils from La Olla 1 (Table 1) suggest that the sequence was deposited over a time span of 260 years from 7890 cal. BP to 7630 cal. BP. The microfossils recorded (Fig. 8) are characteristic of shallow-water and marginal marine environments such as a littoral lagoon. Low species diversity suggests a stressed environment. The dominant presence of
Cyprideis salebrosa indicates a brackish shallow-water phase, with mesohaline waters, for the beginning of the sequence. Foraminiferal assemblages, with high abundance of Quinqueloculina, suggest a marine connection between 7850 and 7800 cal. BP. This is supported by the presences of ostracods such as Leptocythere cf. darwini and Semicytherura cf. clandestina. The scarce number of ostracods recorded between 7780 and 7630 cal. BP indicates unfavourable conditions for the micro fauna. In contrast, high abundance of Ruppia cf. maritima seeds may signify a rise in water level.

The pollen assemblages (Fig. 8) are characteristic of halophytic associations, similar to those described from the estuary of Bahia Blanca (Verettoni, 1961). Several psammophytic taxa characteristic of the present dune vegetation like Ephedra, Phacelia, Calycera crassifolia and Oenothera are present in the pollen record. Xerophytic woodland taxa such Condalia microphylla and Geoffroea decorticans are also present.

Water-level variation of a relatively small water body can be inferred from the fluctuation of taxa associated to the shore of the paleolagoon like Cressa truxillensis and Limonium brasiliensis, together with Cyperaceae and Typha.

The conditions in the littoral lagoon seem to have changed towards the top of the sequence. Although there is an abrupt decline in the presence of Cressa truxillensis and Limonium brasiliensis, the aquatic Ruppia cf. maritima increases between 7780 and 7630 cal BP. These changes are possibly related to an extension of the water body as interpreted from the high abundance of Ruppia cf. maritima seeds. This period of relative high water level coincide with similar conditions inferred from the lacustrine sediments of the nearby sequence Monte Hermoso I (Zavala et al. 1992; Grill, 1993).

Laguna del Sauce Grande

The age model based on the five calibrated radiocarbon dates provides a time control for Laguna del Sauce Grande core expanding the last 3000 cal. BP (Fig. 3).
Figure 8 Abundance of calcareous microfossils (ostracods and foraminifers), macro remains (seeds) and pollen percentages for selected taxa at La Olla 1, including chronology, lithology and total pollen and *Ruppia cf. maritima* concentration. Zones are defined using optimal splitting by information content, applying square-root transformation on the combined microfossil and macro remain data set on LOm and including all taxa within the pollen sum above 1% on LOp. Black bars indicate position and thickness of the samples analysed.
Figure 9 Abundance of ostracods and accompanying biota, pollen percentages and total accumulation rates for selected taxa at Laguna del Sauce Grande, plotted against calibrated radiocarbon ages (cal. BP). Zones are defined using optimal splitting by information content, applying square-root transformation on the LSGm data set (excluding *Limnothrix* cf. *staplinii*) and including all taxa within the pollen sum above 1% on LSGp.
The development of the lake was probably initiated at ca. 3000 cal BP, by the establishment of the river course in its present position (Quattrocchio pers. comm.). Several authors have mentioned the existence of deposits probably associated to palaeocourses of the river Sauce Grande to the west of the present course (e.g. Vega et al., 1989; Bayón and Zavala, 1997). The coastal dunes may have buried the pre-existent relief and force the river to the east (Rabassa, 1982). Zavala and Quattrocchio (2001) present stratigraphical evidence for the evolution of the river Sauce Grande.

Microfossils and macro remains indicate that the lake history begins with a temporary brackish water-phase (Fig. 9). More stable conditions are inferred between 1940-900 cal. BP, when ostracod assemblages suggest a permanent brackish water-phase. However, the high abundance of seeds indicates the presence of a shore near to the sampling point.

The time interval between 900-20 cal. BP is characterized by periods of water level fluctuation. The highest water levels occurred between 655-265 cal. BP, which coincides with a sharp decline in *Limnocythere cf. staplini* together with a drop in the carbonate content of the sediments. Towards the top of the sequence conditions similar to modern ones are established.

Pollen spectra indicate a relatively stable vegetation composition once the lake was formed (Fig. 9). Pollen assemblages reflect the present regional grassland vegetation with taxa characteristic of the surrounding dune communities such as *Discaria americana*, *Ephedra*, *Phacelia*, *Rosaceae* (e.g. *Margyricarpus pinnatus*) and *Plantago* (e.g. *Plantago patagonica*). Xerophytic woodland taxa like *Zygophyllaceae* (e.g. *Larrea*), *Condalia microphylla* and *Prosopis* are frequent in the pollen record although in low quantities.

Human settlement is indicated in the pollen spectra by the presence of introduced taxa in the uppermost samples.

Most of the pollen records from the area, obtained from outcrop sections along fluvial valleys, indicate significant vegetation changes during the last 3000 years (Borromei, 1992, 1995, 1998; Grill, 1993, 1995, 1997, 2003). In contrast, the pollen record from Laguna del Sauce Grande shows only minor changes of the regional vegetation. However, changes in the local vegetation are recorded. These changes correspond to ostracod, macrofossil as well as sedimentological records indicating changes of the water regime in Laguna del Sauce Grande. Work at more sites is needed to resolve the differences and clarify the extent to which the regional vegetation has changed in southern Buenos Aires Province.
4.5. Comparison of fossil and present-day pollen assemblages

Principal component analysis (PCA) was applied on the combined data set of fossil and modern pollen spectra (Fig. 10). The PCA of the combined dataset showed three significant axes explaining 32%, 18% and 12% of the variance. Sample scores on the first two axes are represented in Fig. 10a and scores on the second and third axes are shown in Fig. 10b.

Fossil pollen assemblages from La Olla 1 and Laguna del Sauce Grande plot in discrete clusters indicating a small sample variance within sites but a large difference between sites. The surface samples from ephemeral lakes take a position intermediate between samples from both fossil records. Surface samples from different dune environments show all negative sample scores on the first PCA axis because of their low Chenopodiaceae pollen percentage values. However, these samples are differentiated on the second axis, reflecting variation in the composition of dune vegetation (Fontana, unpublished).

Pollen spectra from Laguna del Sauce Grande compare best with surface samples from back shore and slacks. However, semi-fixed and fixed dune vegetation cover large areas adjacent to the lake. Laguna del Sauce Grande is an extensive water body, receiving pollen from regional sources, which may be the reason for the lack of correspondence between the pollen spectra from these vegetation types and the spectra from the lake. On the other hand, most Asteraceae species as well as *Discaria americana*, both important components of the semi-fixed and fixed dune zones, are insect pollinated taxa which produce pollen grains that are not transported over long distances and thus may be under-represented in the large basin.

Fossil pollen assemblages from La Olla 1 are distinctly different from all other modern samples by their high proportion of Chenopodiaceae pollen. However, if the sample scores on the second and third axes are compared it becomes clear that pollen assemblages from La Olla 1 share features with surface samples from mobile dunes, slacks and fixed dunes.
Figure 10. PCA plot of the taxa combined square root transformed dataset including surface samples, Tauber traps, lake sediment samples and fossil sequences. a) shows the sample scores on the first and second axes, b) shows the sample scores on the second and third axes.
5. Conclusions

This study aimed to describe present and past coastal dune environments in southern Buenos Aires Province, Argentina.

- The coastal dune system at Monte Hermoso is characterized by high floristic diversity and spatial plant heterogeneity. Vegetation mapping revealed a strong zonation of the vegetation cover, regulated by environmental factors. A large number of Poaceae and Asteraceae species grow on the dunes. Dominant species present in almost all the vegetation zones are *Hyalis argentea*, *Panicum urvilleanum*, *Poa lanuginosa*, *Solidago chilensis*, *Aira caryophyllea* and *Hydrocotyle bonariensis*.
- Pollen assemblages from the different vegetation zones often differ considerably from the associated vegetation composition. Some of the major discrepancies are caused by the large differences in pollen and vegetation proportion of *Hyalis argentea* and *Discaria americana*. In addition, there is a considerable proportion of non-local pollen in every pollen spectrum.
- The pollen spectrum from individual traps reflects the dune vegetation at Monte Hermoso as a whole. It can be characterized by: (1) high pollen influx, (2) dominance of Poaceae, Asteraceae, *Discaria americana*, Chenopodiaceae and *Hyalis argentea* and (3) presence of *Calycera crassifolia*, *Oenothera mollissima*, *Plantago patagonica*, *Hydrocotyle bonariensis*, *Schinus* and *Ephedra*.
- A new species of ostracods was recovered from an interdunal lake. This species, a giant cypridid, is described and illustrated and its geographical distribution and ecology are discussed.
- The sediment sequence recovered from La Olla 1 was deposited during the time interval between 7890 to 7630 cal. BP. The microfauna recovered is characteristic for a shallow, marginal marine environment, such as a coastal lagoon. The microfossils indicate a marine connection between 7850 and 7800 cal. BP. Plant macro remains and pollen analysis indicate an extension of the water body after 7780 cal. BP. The pollen record reveals the development of a halophytic plant community in a coastal environment.
- The sediment record from Laguna del Sauce Grande comprises the last 3000 years. Microfossils and macro remains indicate that the lake history begins with a temporary brackish water-phase. This is followed by more
stable conditions between 1940-900 cal. BP. Periods of water level fluctuations occur after 900 cal. BP, with high water levels between 660-270 cal. BP. The uppermost samples of the sequence show similar conditions to present day. Pollen spectra indicate a relatively stable vegetation composition once the lake was formed. Pollen assemblages reflect the present regional grassland vegetation with taxa characteristic of the surrounding dune communities.

In summary, this study provides a comprehensive view of modern pollen depositions and ostracod assemblages in coastal dune environments. Thereby, it can serve as a useful reference for the interpretation of fossil sequences from similar environments.
6. Svensk sammanfattning


Syftet med denna studie är att:

- Beskriva den moderna vegetationen i de kustnära sanddynerna vid Monte Hermoso;
- Etablera en pollenanaloga för de kustnära dynbildningarna samt att undersöka förhållandet mellan förekomst av pollen och den lokala vegetationen;
- Studera artsammansättningen hos ostracoder i sjöar och dammar mellan dynerna;
- Rekonstruera vegetationshistoria och miljöförändringar i kustregionen;

Sandydnernas vegetationen och zonering beskrevs med hjälp av flygfotografier (skala 1:20 000) samt dynsystemens fysionomi och växtsammansättning. Kartering av dynområden, med största möjliga variation i vegetationen, genomfördes i försöksområden om 10*10 m. Samtliga arter inom försöksytorna identifierades och deras täckningsgrad uppskattades enligt Domin-Krajina 10 punkters skala (Mueller-Dombios & Ellenberg, 1974). Ytprover av jordmänen samlades in från varje försöksytas för

Holocena sediment provtogs i La Olla 1 och Laguna del Sauce Grande. Sjösedimenten i La Olla 1 avsattes under perioder med en lägre havsnivå jämfört med dagens nivå. Den moderna miljön karaktäriseras av en kustnära tidvattenzon, vanligen täckt med sand. Under kortare perioder med extremt låga vattennivåer, har området varit exponerat. Sedimenten i La Olla 1 är av stort arkeologiskt intresse då de innehåller information om hur jägar-samlar samhället i tidig Holocen använde sig av de marina resurserna (Politis and Bayón, 1995; Johnson et al., 2000). Laguna del Sauce Grande ligger 8 meter över havet och cirka 4 km från Atlantkusten, 38° 57' S, 61° 22' W. Det är en grund sötvatten sjö med ett medeldjup på 1 meter som täcker ett område på 23 km². Bäcknet är bildat av vinderosion och har sitt tillflöde från floden Sauce Grande.

Vid La Olla 1 togs en sedimentsekvens som är 35 cm lång. Vid Laguna del Sauce Grande togs överlappande 1 meters sekvenser med ryssborr, 5 cm i diameter (Jowsey, 1966). De allra översta, vattenmattade sedimentet togs upp med en Willner ytprovtagare. Den fullständiga sedimentsekvensen i Laguna del Sauce Grande utgörs av 289 cm ostört material.

Sedimenten beskrevs och analyserades med avseende på glödgningsförlust (LOI), ostracoder, foraminiferer, makrofossil samt pollen. Sedimentkärnorna ifrån Laguna del Sauce Grande korrelerades med hjälp av magnetiska parametrar.

För ålderskontroll av sedimentstratigrafierna användes 14C-datering av akvatiska och terrestra makrofossil samt gastropodskal. Frön från vattenväxter i La Olla 1 uppvisar en reservoareffekt på cirka 800 år, däremot kan inga sådana effekter upptäckas hos gasropodskal från Laguna del Sause Grande.


Jämförelser mellan pollenförekomst och den lokala vegetationen visar att pollensammansättningarna i de olika zonerna ofta avviker avsevärt från vegetationen, främst orsakat av stora skillnader mellan pollen och vegetation hos Hyalis argentea och Discaria americana. Dessutom återfinns, på samtliga pollennivåer, en stor mängd arter som inte finns representerade i den lokala vegetationen, "icke lokala" arter.

Båda pollenfällorna domineras likaså av dessa "icke lokala" arter, men den lokala vegetationen finns också representerad. Fälla A, som är placerad på toppen av en dyn, har högre andel "icke lokala" pollen än fälla B. Det
högsta absoluta pollenantalet återfinns i fälla A. Medelvärdet av den totala pollenkoncentrationen i de individuella fällorna avviker inte nämnvärt från varandra. Årsmedelvärdet av pollenkoncentrationen och procentandelarna hos de dominerande arterna visar på obetydliga skillnader mellan fälla A och B, med undantag ifrån *Discaria americana* vilken visar högre årliga koncentrations- och procentvärden i fälla A. Båda pollenfällorna tillsammans erhåller totalt 19 000±9 600 pollenkorn per cm² och år⁻¹. Poaceae och Asteracea förekommer mest, Poaceae med 7 100±3 900 pollenkorn per cm² och år⁻¹ och 39±9% av den totala pollensumman, Asteracea med 5 700±3 400 pollenkorn per cm² och år⁻¹ och 29±6% av den totala pollensumman.

I samband med undersökningen i en av sjöarna mellan dynsystemen, Laguna Caliba, återfanns en ansamling av ostracodskal i kanten av sjön. I denna ostracodskalbank upptäcktes en ny, stor ostracod art. Denna nya art har beskrivits och illustrerats i denna studie. Dessutom ges en kortfattad diskussion om dess geografiska spridning och ekologi.


Laguna del Sauce Grande bildades för cirka 3000 år sedan och var då till en början en brackvattenmiljö. Under torrperioder avsattes vindtransporterad sand från de omgivande dynerna, vilket kan identifieras som tydliga lager i sjösedimenten. Stabilare vattennivåer föreligger mellan 1940 och 900 år sedan, då förekomsten av ostracoder antyder en mer permanent brackvattenmiljö. En stor mängd från visar dock att provtagningsplatsen låg
nära stranden. Perioden mellan 900 och 20 år sedan karaktäriseras av fluktuationer i vattennivån.

Pollendata antyder en relativt stabil vegetationssammansättning när sjön väl har bildats. Den nutida, regionala gräsvegetationen med typiska taxa i den omgivande dynvegetationen som t ex Discaria americana, Ephedra, Phacelia, Rosaceae (e.g. Margyricarpus pinnatus) och Plantago (e.g. Plantago patagonica) återspeglas i pollendiagrammet. Skogsarter typiska för arida områden som t ex Zygophyllaceae (e.g. Larrea) Condalia microphylla och Prosopis förekommer i små mängder. Förekomsten av introducerade arter som t ex (Pinus Eucalyptus) i pollendiagrammets övre delar antyder mänsklig påverkan i området.
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A doctoral dissertation from the Faculty of Science and Technology, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series *Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology*. (Prior to October, 1993, the series was published under the title “Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science”.)