Ecological dynamics and main criteria for the rehabilitation of a littoral marsh (Albufera of Majorca, Balearic Islands)

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Introduction

The *Albufera* of Majorca has an approximate extension of 24 km². It lies to the northeast of the Island and has been recognized by the UICN, INRB and ICBP as an area of conservational interest.

During the last century it was almost completely dried up and transformed from a zone of divergent waters that formed many small ponds into a group of channels where the waters are forced to reach the sea through the shortest and fastest way (fig. 1). This criterion, while useful for desiccation, is the less natural for the normal course of the waters. When the potential energy is low the waters tend to spread out and occupy the widest area before arriving to the sea.

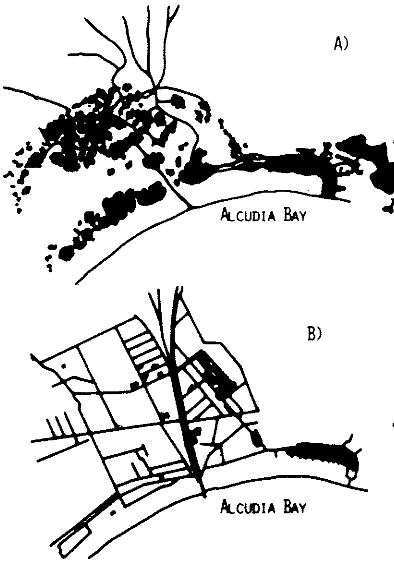

Fig.1.- (A) Before 1859
(B) 1988

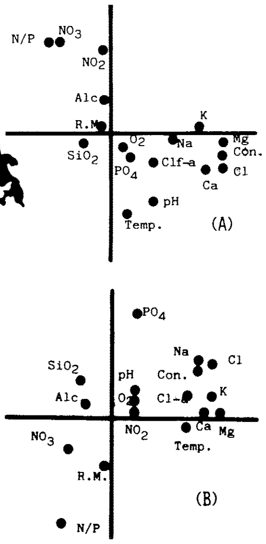

Fig.2. (A) Coastal lagoons
(B) Channels

The environment of the *Albufera* include artificial and natural lenitic zones as well as artificial lotic zones. Both types of environments have been studied separately by means of factorial analysis to understand the general features of the system.

Coastal lagoons

Parameters related to the salt contents are strongly correlated and offer high charge coefficients over the first axis which can be related with marine influence.

As factors of positive charge the second axis shows the nitrogen components and as negative the pH and the temperature. This axis can be interpreted as a production gradient. In fact, higher temperatures, an increasing in the pH and a decreasing of nutrients take place in moments of active photosynthesis (fig. 2).

It could be expected that the phytoplanktonic chlorophyll "*a*" would be much more related to the temperature and the pH. The reason comes from the fact that primary production is carried on mainly by aquatic macrophytes which compete advantageously with phytoplankton. Therefore the second axis must be linked to the performance of phytobenthic communities.

Channels

The charge factors of the first axis are similar to those described for coastal lagoons and the second axis presents phosphates as the principal positive charge factor, and the relation nitrogen-phosphorus as the main negative charge factor. Nutrients are originated in two different areas. From the upper part of *Albufera* arrives the contribution of the crop fields and from the lower part arrives a direct input of urban origin. The gradient that appears in the second axis is established between these two extremes (fig. 2).

Rehabilitation criteria

Coastal lagoons depend on natural processes, salinity variations and macrophyte activity. Lotic environments also depend on marine influence but also are affected by an artificial influence.

Desiccation has caused an increase of helophytic vegetation, which ocuppies nowadays 96% of the humid zone. Filling of lagoons and geometrical arrangement of currents forces submerged vegetation to be lotic adapted while other species, more adapted to lenitic environments, are decreasing or have disappeared, as *Trapa natans* or *Nymphaea alba* (MARTINEZ TABERNER, 1986).

Basic criteria for rehabilitation would be the following:

1. Reassure the present dynamics of the lagoons and eliminate those disturbing factors of the lotic environments.
2. Increase free water zones by progressively restoration destroyed lagoons in order to achieve a rise in food resources and in the number of habitats (AGAMI & WAISEL, 1986; BJÖRK, 1972; ENGEL, 1984).
3. Change water circulation pattern in order to fractalize its route.
4. Avoid environment regularity and try to smooth the gradient so that it can be occupied by a great number of species with different environment tolerances (LYNCH & GABRIEL, 1986).

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The Albufera of Valencia, an hypertrophic stressed ecosystem

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INTRODUCTION

The Albufera of Valencia is the largest oligohaline coastal lagoon in Spain. It is a shallow water body (mean depth of 1 m) with a surface of more than 22 km . Historically it has suffered important human impacts which can be summarized as: (1) transformation of marsh-lands into rice fields mainly during XIX century; (2) industrial development and population increase since 1960. The Albufera receives the flow of about 50 channels coming from adjacent ricefields and a few streams, all of them heavily contaminated with domestic and industrial sewage waters. In the last 25 years this lagoon has shifted from a transparent and clear water body above macrophyte prairies to an opaque green water body over a anoxic black sediment. The intention of the present paper is to show and to evaluate the factors causing this change. Previous papers (Soria et al, 1987; Oltra and Miracle, 1984; Serra et al, 1984) have been dedicated to the state of the Albufera since 1981. The present paper is an integrated study comparing the limnology of the inflowing channels with that of the lagoon.

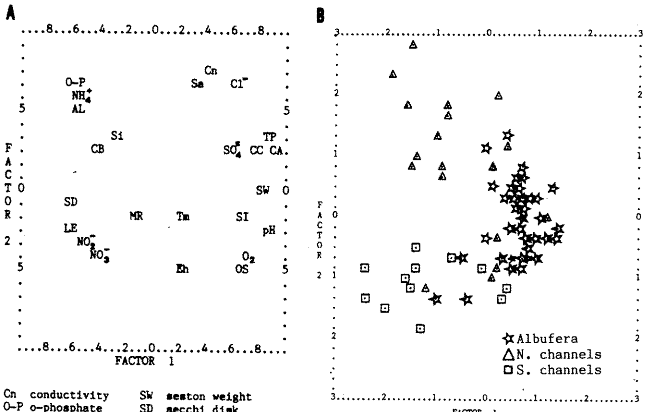
RESULTS AND DISCUSION

Samples have been taken during an annual cycle (year 1985) from the mouth of channels arriving from the Northern part heavily contaminated by sewage and from the Southern part comprising agricultural waters with some domestic effluents. Samples were taken also from several points inside the Albufera. Table 1 shows mean values for these three sets of samples. Domestic and industrial effluents are loaded with phosphorus and ammonia, while agricultural waters are rich in nitrates. On the other hand, the waters inside the Albufera have relatively low concentrations of nutrients. However, the stress, produced in the lagoon, by the nutrient load, is shown by the extremely high chlorophyll contents and primary production values. Other parameters associated with primary production such as pH and alkalinity, vary accordingly; they are respectively high and low inside the lagoon. Primary production is limited to the surface, because the high phytoplankton density (c.a. 2 million individuals/ml or their biomass equivalent, 300 mg/l) determines the light extinction coefficient (secchi disk values vary around 0.1-0.2 m). Maximum primary production in late spring reaches 7 g C/m² .day and the minimum in winter is arround 2 g C/m².day. A principal components analysis (fig. 1) was made with the samples characterized by the physicochemical and biological variables indicated in fig. 1A. The first component can be associated with eutrophy: photosynthetic pigments, seston and oxygen have the highest loadings at the positive end while nutrients, alkalinity and light penetration have the highest loadings at the negative end. This component separates the Albufera samples from the channel samples. The second factor is determined by orthophosphate, ammonia, alkalinity and salinity at the positive end versus nitrate, nitrite oxygen, redox and light penetration at the negative end. It separates the Northern from the Southern channels. Phytoplankton in the channels is dominated by chlorophyceae or diatoms, but the lagoon is densely populated throughout the whole year by continous blooms of cyanobacteria and heterotrophic bacteria.

In conclusion, the Albufera functions both as a quimiostat and a sewage purificative treatment pool. Great amounts of nutrients and organic matter enter into the lagoon, whose outflow is almost free of limiting nutrients. On the other hand, in the lagoon, nutrients and organic matter are converted into biomass, which is removed from the system into the sediment, but some fraction of it is exported through the outflows to the sea.

Table 1. Annual means for 1985 of nutrients and other parameters associated with phytoplankton growth inside the Albufera and in the most representative inflow channels. The primary production inside the lagoon is 1 g C/m³h in the surface and 0.05 g C/m³h at 0.5m. Nitrate, ammonia and orthophosphate in µmol/l, alkalinity in meq/l and chlorophyll in µg/l.

	NO_3^-	NH_4^+	O-P	Alk.	pH	Chlor.a
Industrial + domestic sewages (North)	9	1300	113	4.3	7.9	70
Agricultural waters (South)	390	50	5	3.9	7.7	10
Albufera	32	10	0.1	2.3	9.0	340



Cn	conductivity	SW	seston weight
O-P	o-phosphate	SD	secchi disk
Sa	salinity	MR	ratio 433/665
Cl⁻	chloride	Tm	temperature
NH_4^+	ammonia	SI	seston individuals
AL	alkalinity	LE	1% light penetration
Si	silica	pH	pH
TP	total pigments	NO_2^-	nitrite
CB	chlorophyll b	NO_3^-	nitrate
$SO_4^=$	sulphate	O_2	oxygen
CC	chlorophyll c	OS	oxygen saturation
CA	chlorophyll a	Eh	redox potential

Fig. 1. Principal components analysis. (A) Factor loadings of the physicochemical parameters. (B) Plot of samples in the space dimensioned by the first two factors.

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