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LIMNOLOGY OF A RICE FIELD: A CASE APPROACH TO «AIGUAMOLLS DE L'ALT EMPORDÀ» (GIRONA, CATALONIA)

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RESUM

Hem analitzat els paràmetres físico-químics en els camps d'arròs de nova inundació durant un cicle anual. Aquests arrossars es troven prop de la Reserva Natural dels Aiguamolls de l'Empordà (Girona). Els punts de mostratge foren seleccionats segons una distribució en l'espai i el temps i de l'origen de l'aigua. Analitzem estadísticament els resultats obtinguts. S'analitzen també les conseqüències de la dinàmica dels nutrients en el camp d'arròs sobre les comunitats dels aiguamolls pròxims.

RESUMEN

Se han analizado los parámetros físico-químicos en los campos de arroz de reciente inundación durante un ciclo anual. Estos arrozales se encuentran cerca de la Reserva Natural de «Els aiguamolls de l'Empordà» (Girona). Los puntos de muestreo fueron seleccionados según una distribución en el espacio y el tiempo, y por el origen del agua, se analizan estadísticamente los resultados obtenidos. También se evalúan las consecuencias que la dinámica de los nutrientes en el arrozal pueda tener sobre las comunidades de las marismas cercanas.

ABSTRACT

The physico-chemical parameters were analized during an annual cycle in the rice fields near coastal lagoons of Natural Reserve «Aiguamolls de l'Empordà» (Girona, Spain). Sampling points were selected following spatial and water origin distribution. Statistical analysis were performed with the results. The consequences of the dynamics of nutrients on the rice field over the natural marshes neararound are discussed.

Key words: rice fields, dynamics, nutrients, fluxes, phosphates, urea.

INTRODUCTION

The ecological equilibrium of water bodies usually is altered by the influence of human activity (e.g. agriculture) that tend to alter the water quality.

During the last decades it has become clear that strict control on agricultural activities, among others, is needed in order to keep the basic standard quality of natural waters. This control becomes even more critical near natural reserves, where especial communities are tryed to be kept save. In our case the sensitive area is the coastal marshes of «Aiguamolls de l'Alt Empordà» (Girona) (Farràs, 1985).

The aim of this work is to study the evolution of selected limnological parameters in a recently stablished rice fields (Fig. 1). This gave us an oportunity to study the evolution of a new cultivation along different season as well as its influences over the surroundings. The marsh «La Massona» is fed with freshwater coming from the channel «Rec Gallinera» and, indirectly, by salt water from seepage and by marine eastern storms. Since the onset of rice cultivation, part of the freshwater channel was derived to flood the fields, and at the same time, water level was controlled by releasing freswater excess to «La Massona» lagoon.

This study tries to determine the changes in water quality and composition along the rice life cycle, which starts in March with field roturation. During April, the flood is stablished and kept till October. Seedbeds are planted in May and harvested during October. Fields are twice manured, in April and June, receiving each time 200 kg urea per hectare, as the unique fertilizer, resulting in 35 mg of total nitrogen per litre of water.

A surplus water was aported to the cultivation fields from wells which

Figura 1. Aerial overview showing the rice fields extension and the coastal marsh lagoon «La Massona». Scale 1:9500.

bring water from 40 m depth. Another superficial well from residual water of a nearby camping site was also used as emergency supply during summer.

Thus, these three different water origin, «Rec Gallinera», freatic wells and residual organic water well, were necessary to keep water depth to a minimum of 20 cm all over the 40 hectares of the rice field.

MATERIAL AND METHODS

Temperature, dissolved oxigen, conductivity and pH were measured directly in the field using respectively, a combined termistor and oximeter YSI 57, conductimeter and pH-meter Crison.

Red-ox potential was measured by means of a platinum electrode Methrom AG 9100. Laboratory analysis of saluble reactive phosphate, nitrite and nitrate were done following Strickland and Parsons (1968) and Margalef (1977).

Samples were taken weekly and sometimes bewekly from thirteen points, from June till September, at the same time of the day and at the half depth of water column. Some sampling points, as indicated in table 1 were sometimes dry.

The results were statistically analyzed trough a two-way anova analysis in order to find significative variations of parameters along time and between different sources. A randomized block design as a mixed model of anova with sampling points as fixed factor and date of sampling as blocks was done (Sokal and Rohlf, 1969).

RESULTS

Although there were more sampling points (thirteen), only five of them —following a similar sampling metodology used in rice fields of the Ebre delta (Forès, 1985)- will be shown here (Table 1 a-l). Three of them are

Table 1.a. Results of the analysis of selected parameters in sampling point (A): «Rec Gallinera».

Date	T°C	pH	O_2 ($mg.L^{-1}$)	Conductiv. ($\mu s.cm^{-1}$)	Red-ox (mV)	Phosphate (mM)	Nitrite (mM)
3.7.85	22.0	7.8	—	705	—	2.1	134.7
10.7.85	22.5	—	4.2	1094	—	2.3	68.7
19.7.85	22.0	8.3	2.5	745	245	3.7	300.0
25.7.85	22.0	7.4	1.8	873	242	4.1	289.7
1.8.85	20.0	7.0	1.0	642	291	17.6	206.9
8.8.85	18.0	7.5	1.3	1180	286	19.7	195.4
22.8.85	20.5	7.5	1.5	1700	277	5.6	42.1
3.9.85	20.0	7.3	1.1	5270	270	4.4	201.8
16.9.85	20.5	7.9	8.5	1401	—	—	—

Table 1.b. Results of the analysis of selected parameters in sampling point (B & C): freatic wells.

3.7.85	16.5	—	6.6	2051	—	1.7	33.2
10.7.85	16.0	8.4	4.5	2854	231	2.5	80.1
19.7.85	16.0	7.2	4.5	3534	242	3.2	35.3
25.7.85	17.0	7.5	1.9	2868	301	13.9	36.1
1.8.85	19.0	7.7	4.7	3700	286	7.5	7.1
8.8.85	16.0	—	—	—	—	—	—
22.8.85	16.5	7.7	4.5	5830	255	3.3	94.4
3.9.85	16.0	7.3	7.5	5270	—	10.4	74.4
16.9.85	16.0	—	—	—	—	—	—

Table 1.c. Results of the analysis of selected parameters in sampling point (D): Residual organic well.

22.8.85	—	8.5	—	—	—	7.05	59.6
3.9.85	—	8.9	—	—	—	23.36	68.7
16.9.85	—	8.5	—	—	—	21.06	55.1

Table 1.d. Results of the analysis of selected parameters in sampling point (E): rice field central area.

3.7.85	26.0	—	10.3	770.3	—	—	189.6
10.7.85	23.5	8-5	5.0	700.0	286	1.8	<300.0
19.7.85	24.0	6.5	4.5	951.4	232	2.2	25.8
25.7.85	24.0	7.1	—	731.3	—	5.7	43.9
1.8.85	21.0	—	2.7	—	285	18.1	—
8.8.85	17.0	7.8	6.3	1681.0	279	1.1	261.4
22.8.85	23.0	—	6.5	—	266	—	—
3.9.85	22.0	7.4	7.3	1983.8	—	7.2	89.2
16.9.85	20.0	—	—		—	3.5	—

Table 1.e. Results of the analysis of selected parameters in sampling point (F): outlow channel.

3.7.85	26.0	—	9.8	653.2	—	0.8	226.6
10.7.85	23.0	9.7	5.5	550.9	286	2.6	50.8
19.7.85	23.5	6.9	3.2	1533.6	232	2.2	34.4
25.7.85	22.5	7.5	1.5	—	—	—	36.1
1.8.85	22.0	7.5	4.5	3570.0	285	3.8	30.1
8.8.85	21.0	8.9	14.2	3100.0	279	5.9	68.7
22.8.85	22.0	—	—	3650.0	266	13.2	77.9
3.9.85	22.0	7.9	8.6	2830.0	—	29.7	0.0
16.9.85	21.0	8.3	—	2870.0	—	15.9	0.0

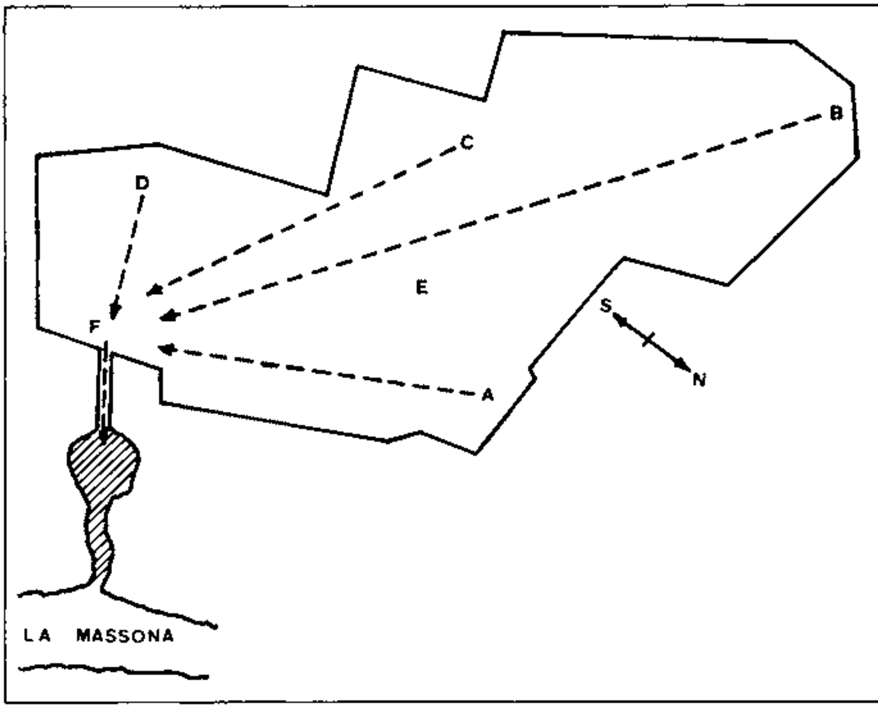

Figura 2. Schematic map of the rice fields showing the sampling points: A, «Rec Gallinera» channel; B, C freatic wells; D. residual water well; E, central area; and F. exit channel. Arrows indicate the main water flux. Scale 1:5400.

water entries, one from the «Rec Gallinera» channel, another one from residual waters of camping site and the third from two freatic wells (both freatic wells do not show significative diferences and are indicated as a unique point). The last two sampling points were a central one located into the rice fields and another in the outflow channel (Fig. 2).

The water in the rice fields presents a temperature range between 20 to 25 °C with minimal values of 16 °C while freatic water comes out from wells. Temperature variation in five degrees is closely related to the rainfall dynamics during the studied period. (Fig. 3a).

Although high temperature variation appears in the daily cycle, they follow a similar pattern except during rainfalls. The relationship between the rain dynamics and variation in water conditions is algo observable in other parameters and is, probably, a consequence of the shallowness of water column in rice fields. Rain can represent a relatively very important water surplus, and at the same time provoques changes in the flux, lixiviation intensity and dilution rate (Fig. 3 b and c).

The pH oscillates from 7.5 to 8.3 with extreme values of 6.4 and 9.5. There appears to be a general, but slight, tendency to acidification. This fact could be the result of an intensive nitrogen cycle in the rice fields. pH values do keep quite constant in the wells all along the season (Table 1).

Conductivity presents great variations in accordance with the coexistence in the cultivation of fresh and marine water sources like the salt saturated ground. Also, evaporation was very important during the summer, increasing the salt contents of the water. A significant increase in the levels of conductivity is observed in the freatic water comming from wells, making clear the intrusion of sea water in the freatic level.

Oxigen concentration were, in general, quite high corresponding to the intense algal photosynthesis that took place in the fields. Again, daily variations are present but, in general, oxigen levels are stable and balanced both by the algal populations and heterotrophic consuming activities. In sampling points where water was specially low, sediment turbidity is present, and hence, oxigen concentration is much lower in accordance with higher reducing conditions.

Red-ox comes as the most stable parameter in the fields with values from 216 to 280 mV. No significative ($P<0.01$) variations are observed among different points of sampling. The evolution is similar to all points, and do not show significative variations. Again, in the points where sedi-

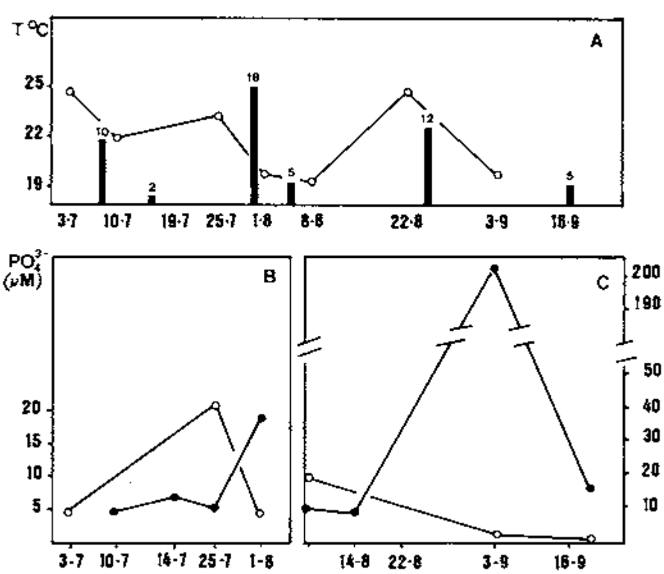

Figura 3. Panel A. Effect of rain (vertical bars in liters per m^2) on temperatura (o) of water in rice fields in central sampling point E. Panel B. Changes in phosphate concentration in outflow channel F where accumulation predominates (•) as compared to rain washing effect in central sampling point E (o). Panel C. Changes in phosphates concentration in «La Massona» lagoon (•) which acts as receiving water body as compared with the outflow channel F (o) during 1985.

ment turbidity is present, lower red-ox potentials are found in the water.

Nitrates and nitrites are found at very high values (fields were fertilized with urea), with a slight tendence to decrease during time. The wells do not present such high concentrations of total nitrogen and their own concentration changes do not seem to be related with those observed in the central field sampling point.

Phosphates show an heterogeneus distribution along the surface of the fields. Wells were the major sources of phosphates. In the field, each well creates an area of influence where phosphate concentration displays similar characteristics and where temporal changes correspond with the phosphate concentration in the well water.

At the same time, phosphates seem to acumulate at the lower parts of the fields near the outflow channel, were concentration increase to high levels (e.g. 29 $mM.L^{-1}$). A high relationship among phosphate balance and the rain is detectable, and a clear pattern of lixiviation and acumulation appears (Fig. 3b).

The effect of lixiviation induces a circulation of phosphates from the rice fields to the marsh «La Massona» partially increasing the nutrient concentration (Fig. 3c), (Dominguez-Planella, 1987).

DISCUSSION

An overview of the changes of limnological characteristics i the rice fields appears to be as follows: water influx seems to have an important nutrient concentration (mainly phosphate) which is incorporated into the rice fields in different ways. Nitrogen is added, in excess, by means of urea fertilization (Fig. 4). This excess probably inhibits biological nitrogen fixation that, otherwise, would be very active (Burns & Slater, 1982, Swaminathan, 1984).

Phosphates enter, mainly, from the residual water well near the camping site and its dynamics is strongly determined by meteorological conditions. The freatic wells give phosphate contaminated waters and produce an accumulation of these compounds. After being introduced into the marshes they produce an eutrophication in the receiving marsh ecosystems (Fig. 3c).

The red-ox potential, together with the results observed in the oxigen analysis, suggest the existence of intense heterotrofic oxidation processes in the water, making clear that a strong influence from the reducing sediments is present. Again this influence is the result of the low water level in rice fields that disable the posibility of existence of a more stable water column.

With the exception of the eutrofication process the rice fields promote in the nearby salt marshes communities, no other negative influences are observable from the results of this work. In contrast, paddy fields could represent an important area for the natural reserve since it represents a first-class feeding area for migratory birds as wader or long-legs (Hayman, 1986). At the same time, could be a posible source of increased zoological diversity in the area, since they are fresh water extensions among a traditio-

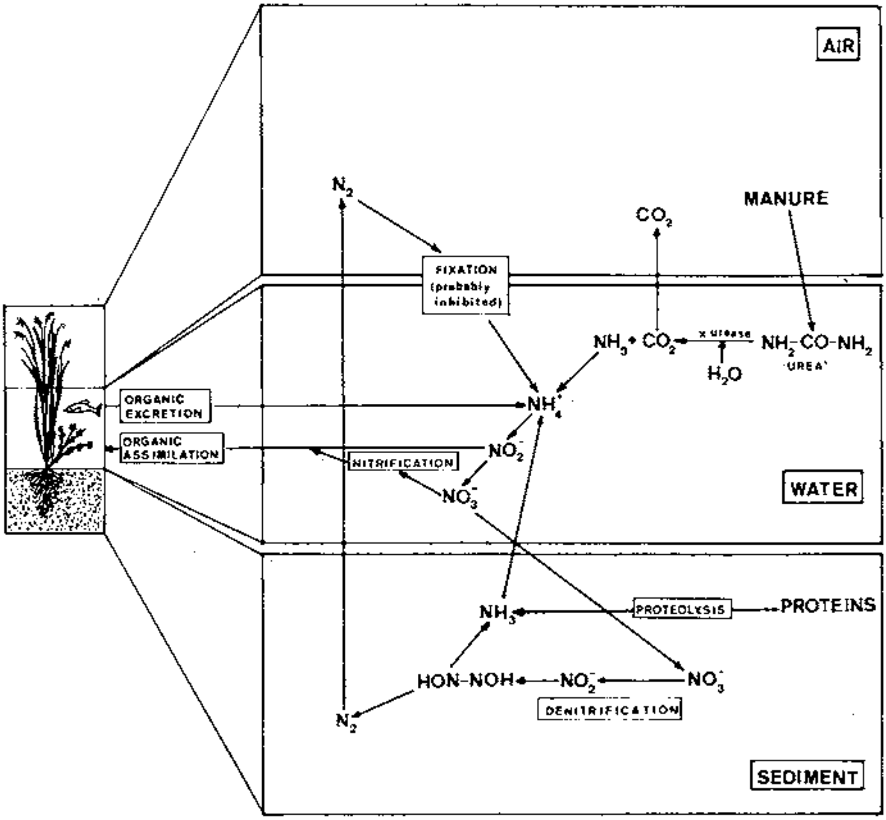

Figura 4. Ideal scheme showing the nitrogen cycle in rice fields.

nally highly salt-saturated waters. These kind of interrelationship should be further studied.

Concerning the phosphate contamination in freatic waters the problem could be easily solved by replacing the well which take residual superficial water by deeper freatic wells which do not present organic or phosphate contamination.

It is difficult to compare the limnological conditions of the rice fields studied in our area with the studied by Forès (1985) in the Ebre delta. Flooding conditions, manuring systems and compounds used, and other characteristics are different in both areas. Even so, some chemical features are coincident and suggest that they have some ecological processes in common. In his way, salt concentrations are much lower in the Ebre delta due to the different geological origins of both areas. Red-ox potential also expresses the sediment influence in the fields of the Ebre delta. This coincidence makes us think that studies in the sediment evolution are crucial for understanding the whole processes. Part of this analysis has already been done by Forès (1985).

An important circulation of phosphates from the fields to the fields to the marshes was observed in the Ebre delta, although there have been no studies trying to find the relation of this process with frequency. This type of eutrofization with important effects in the delta marshes seem in that case more difficult to control, since the water used to flood the rice fields is not free both of organic and inorganic nutrients.

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