

Hydrochemistry characterisation of protected marine ecosystems in Cadiz

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ABSTRACT

Wetlands have a great natural wealth due to their borderline nature, representing the point where lithosphere, hydrosphere and atmosphere converge. The wetlands of Cadiz, at the southern extreme of Europe, also play an important role as a stopover area for migratory birds.

This paper presents the results of a sampling project conducted during the spring of 1997 in the Guadiaro and Palmones Rivers, the Barbate estuary, Sancti Petri sound, and the San Pedro River salt marsh. For each system, three sampling stations were established along a salinity gradient, and these variables were measured: salinity, pH and chloride, sulphate, sodium, potassium, calcium, magnesium, nitrite, nitrate, silicate ammonia, organic carbon, dissolved oxygen, chlorophyll and phaeopigment concentrations.

Several behaviours were found for the various systems: the Guadiaro and Palmones Rivers fit a fluvial estuary pattern, with low ionic concentrations and poor remineralisation. The San Pedro River and Sancti Petri sound are tidal systems with a typical seawater composition and high benthic regeneration. The Barbate estuary represents an intermediate scenario between the preceding ones, with a pronounced salinity gradient along its course.

Key words: Wetlands, protected system, estuary, birds, nutrient, Cadiz.

RESUMEN

Caracterización hidroquímica de los ecosistemas marinos protegidos de la provincia de Cádiz

Los humedales tienen una gran riqueza natural debido a su carácter de franja donde convergen litosfera, hidrosfera y atmósfera. Los de la provincia de Cádiz, en el extremo meridional de Europa, tienen además una gran importancia como lugar de paso de las aves migratorias.

En este trabajo se exponen los resultados obtenidos durante la primavera de 1997 en los estuarios de los ríos Guadiaro y Palmones, el estuario del Barbate, en las marismas del Caño de Sancti Petri y las del río San Pedro. Para cada uno de los sistemas se establecieron tres estaciones de muestreo a lo largo del gradiente de salinidad, y se determinó la salinidad, el pH y las concentraciones de cloruro, sulfato, sodio, potasio, calcio, magnesio, nitrito, nitrato, silicato, amonio, fosfato, carbono orgánico, oxígeno disuelto, clorofila a y feopigmentos.

Se encontraron diferentes comportamientos para los distintos sistemas: el Guadiaro y el Palmones responden a un patrón de estuario de tipo fluvial, con concentraciones iónicas muy bajas y una escasa remineralización de la materia orgánica. El río San Pedro y el Caño de Sancti Petri son, por el contrario, sistemas mariales con aguas de comportamiento típicamente marino y una alta regeneración bentónica. El estuario del Barbate es una situación intermedia entre las anteriores y posee un marcado gradiente de salinidades a lo largo de su cauce.

Palabras clave: Humedales, sistema protegido, estuario, aves, nutriente, Cádiz.

INTRODUCTION

The importance of wetlands lies in the fact that these ecosystems, distinguished by shallow water topography and good illumination, have high primary production that makes them suitable habitats, even the only ones for a number of bird species. This aspect of wetlands is particularly striking in southern Andalusia, because the area is not only home to autochthonous and permanent birds, but during certain periods gives refuge to many migratory species which cross the Straits of Gibraltar.

However, they are also environments very vulnerable to anthropogenic actions. Therefore, they have been provided with some official protection to guarantee their conservation. The Andalusian Regional Government's Environmental Protection Agency has developed in recent years several plans designed to evaluate environmental resources and the impacts on the ecosystems, and to identify their causes (Anon., 1996). With this objective, we designed the project Characterisation of the Hydrochemistry of the Protected Wetlands in Cadiz to determine their physico-chemical parameters and the factors that control the structure, as well as the dynamic for its later environment quality diagnostic. Our final objective is the inclusion of the data set in the scientific information network on the Andalusian environment, which will enable us to then elaborate a monitoring plan for the preservation of wetland waters.

This paper presents the preliminary results of this project, related to littoral ecosystems. The objectives were to establish the physico-chemical characteristics of five coastal systems and to analyse the hydrochemical characteristics of those wetlands.

MATERIALS AND METHODS

The coastal wetlands studied are located in the southernmost area of the Iberian Peninsula. Beginning at the eastern extreme of Cadiz province, the first one is the Guadiaro River Natural Reserve (figure 1). This is the only estuary in Cadiz whose fluvial character predominates over its tidal one, because the Mediterranean Sea has a low tidal range and cannot easily penetrate into the estuary. In the mouth of the Guadiaro River, the residential development Sotogrande exercises a major anthropogenic influence. In spite of the

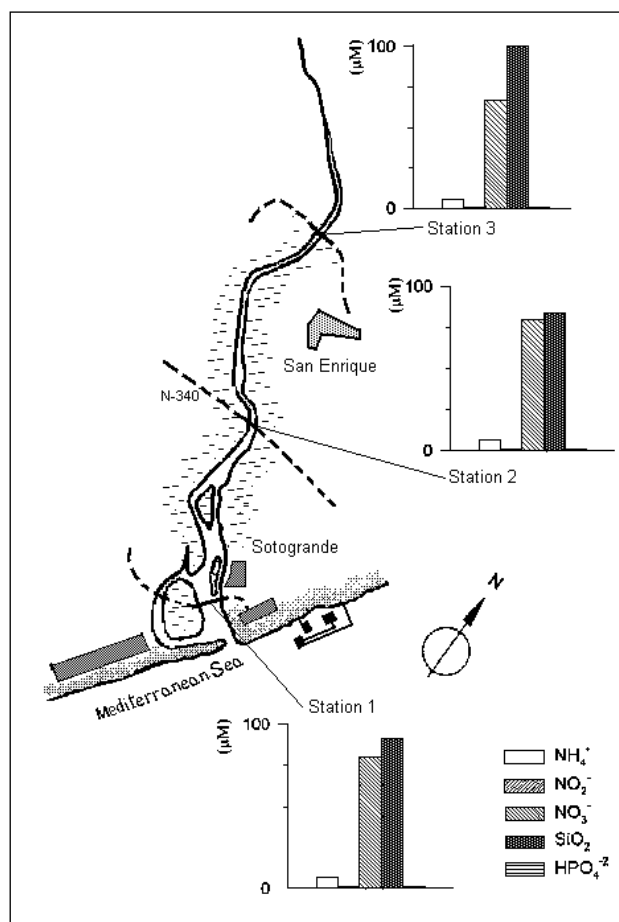


Figure 1. Distribution of nutrients at the three sampling stations in the Guadiaro River estuary

area's deterioration, it remains attractive to water birds, especially in migratory periods.

The following wetlands are located in the Palmones River Salt Marsh Natural Reserve (figure 2). Although this river flows into the Mediterranean Sea, it is highly influenced by the tidal regime of the Atlantic Ocean. This situation has led to salt marshes establishing themselves over former swamp flats. The proliferation of algae on the mud-flat can produce strong and continuous coverage. This abundance could be related to the dumping of organic matter along the riverbed. Rushes are dominate the shore level, indicating that despite tidal inundation, water salinity is attenuated by freshwater contributions.

The next studied system is located in the Barbate River Salt Marsh Natural Park (figure 3). This salt marsh is in an advanced phase of the natural evolutionary silting process, because tidal swamping incidence has been slackening on behalf of freshwater contributions. The desiccation of Lake La

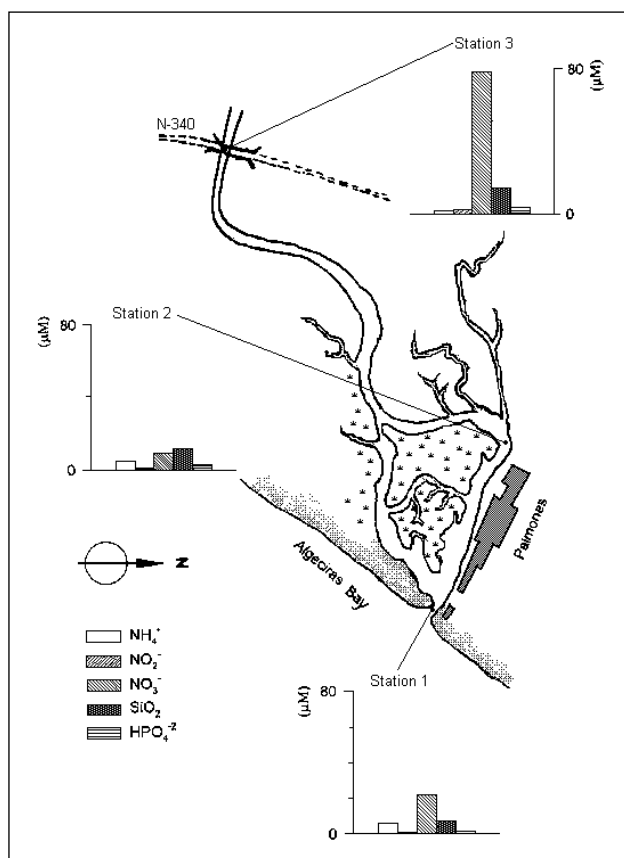


Figure 2. Distribution of nutrients at the three sampling stations in the Palmones River estuary

Janda due to anthropogenic influences has modified the river's hydrodynamic. Therefore, all of the effluent discharges into this lake are now draining into the salt marshes. On the left shore, there is a considerable stretch of former swamp transformed into salt flats, in most cases abandoned. On the shores of sounds and tidelands, there is much bird life, including numerous shorebirds, especially in autumn and winter.

The last two systems are located in Cadiz Bay Natural Park. Sancti Petri sound (figure 4) was an ancient part of the Guadalete River, and is now the link between the inner part of the bay and the Atlantic Ocean. There are currently a low number of natural salt marshes, because most of them have been transformed into salt flats. Nevertheless, these salt flats have considerable ecological interest because they are the wintertime refuge, or permanent habitat, for a varied and abundant bird population. At sampling station 3, raw sewage is dumped from the city of San Fernando (pop. 100 000).

Finally, the system located at the San Pedro River salt marsh (figure 5) comprises a tidal sound with

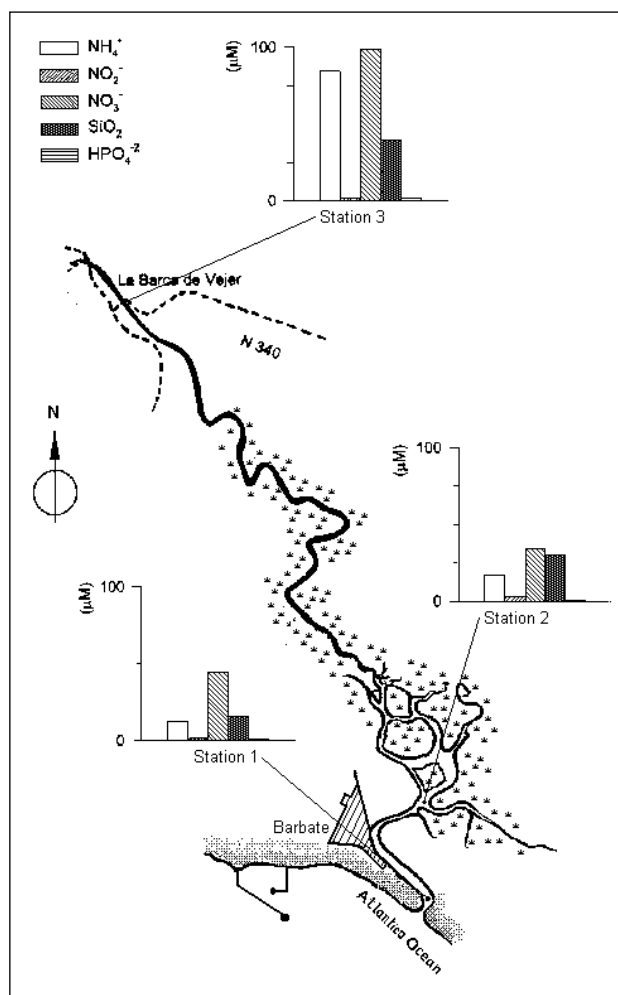


Figure 3. Distribution of nutrients at the three sampling stations in the Barbate River estuary

its wider mouth opened to outer Cadiz Bay, and the other closed artificially. On the right bank, there is one of the few remaining natural salt marshes on the bay.

In each system, we established three sampling stations along a salinity gradient, shown in figures 1 to 5.

Table I shows these measured variables, as well as the methodology and the equipment used in each case.

RESULTS AND DISCUSSION

Figure 6 shows the composition, expressed as majority ions, of the three systems with different hydrochemistry characteristics. In each one are shown the three stations from left to right from the mouth to the head. Chloride and sodium concen-

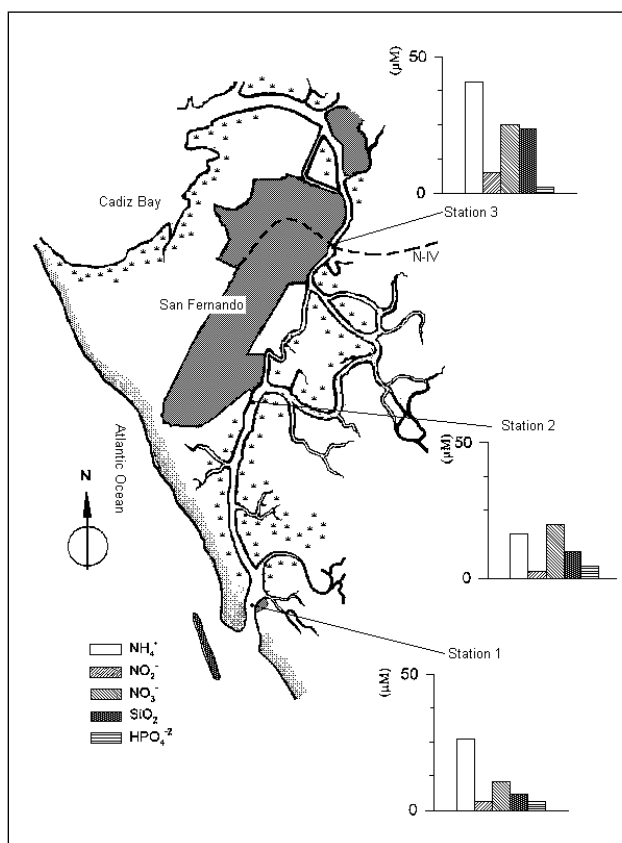


Figure 4. Distribution of nutrients at the three sampling stations in Sancti Petri sound

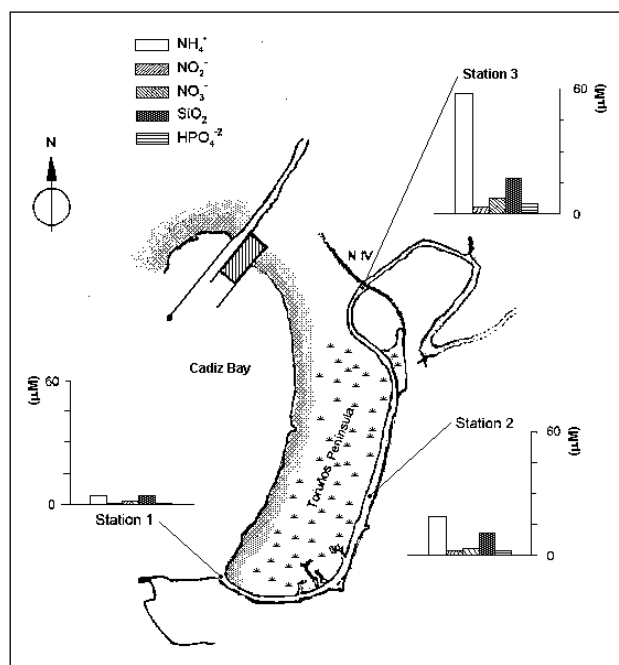


Figure 5. Distribution of nutrients at the three sampling stations in the San Pedro River

trations are shown on the left-hand scale, whereas sulphate, calcium, magnesium and potassium concentrations are shown on the right-hand, one with values substantially lower than those preceding.

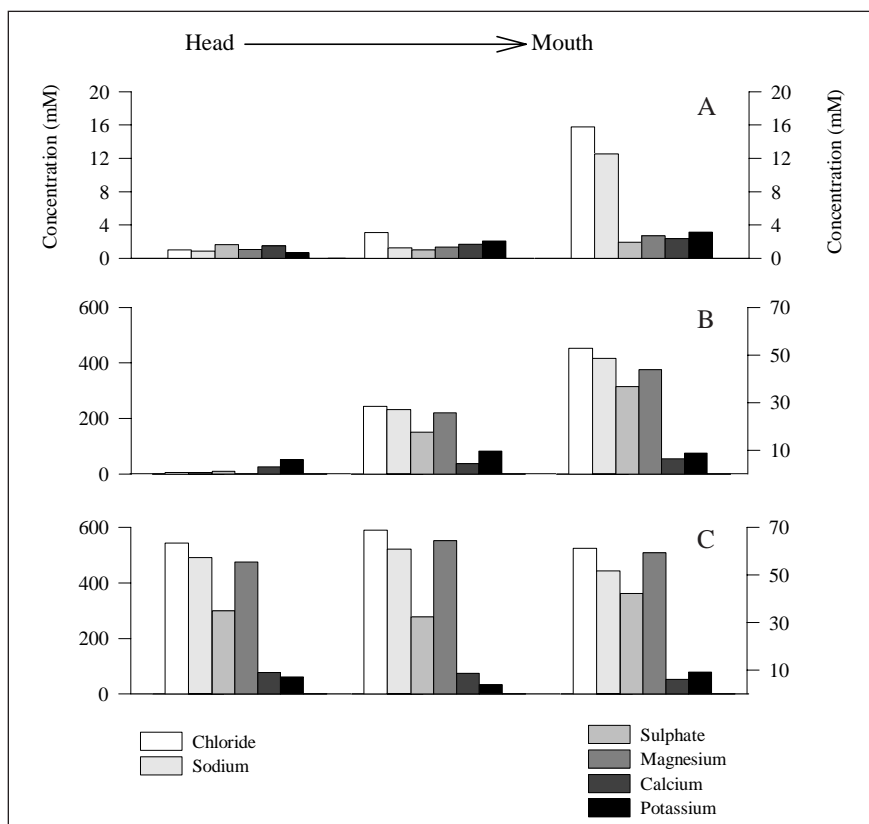


Figure 6. Concentration of majority ions at three stations, from head to mouth, in: (A): Guadiaro River estuary; (B): Barbate River estuary; (C): Sancti Petri sound

Table I. Variables and analyses methodology and equipment used

Variables	Methodology
NH ₄ ⁺ , NO ₂ ⁻ , NO ₃ ⁻ , PO ₄ ³⁻ , SiO ₂ , C.O.D.	Spectrophotometry (Autoanalyzer TRAACS 800)
N _{Total} , P _{Total}	U.V. digestion (705 UV digester, Metrohm) and spectrophotometry
Chlorophyll- <i>a</i>	Method of Parsons, Maita and Lalli, 1984
Salinity	Salinometer (Beckman RS-10)
Cl ⁻	Automatic titration (Metrohm Titroprocessor)
CO ₃ ²⁻ , HCO ₃ ⁻ , pH	Automatic titration (Metrohm Titroprocessor)
Dissolved oxygen	Winkler method, adapted by Strickland and Parsons, 1972
SO ₄ ²⁻	Gravimetry
Suspended and volatile solids	Filtration and weight
Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺	Atomic absorption spectrophotometry (Perkin Elmer 3110 Spectrophotometer)

The Guadiaro estuary has a strong fluvial character, with low concentrations of every major ions at three stations. Opposite to it, the Barbate River shows typical estuarine behaviour (Boyle *et al.*, 1974), with an important increase in these ionic concentrations approaching its mouth. Sancti Petri sound, a marine-type system, has a relatively constant composition and few salinity variations, due to its low volume of urban wastewater effluents.

Figures 1 to 5 show the distributions of nutrients at the three stations for each system. In the case of the Guadiaro River (figure 1), the most important feature is the high concentration of silicate, indicating the continental nature of the estuary water (Millero and Sohn, 1992). Regarding nitrogen, the predominant species is nitrate, suggesting that it is a relatively stable environment with low nitrogen production related to organic matter degradation processes (Klump and Martens, 1989).

In the Palmones River, we can observe enhanced nutrient concentrations as we move upstream. This behaviour is connected with the dam situated at the head that bring about the of organic matter dumped along the river bed by various industries. It happens fundamentally at the closer zone of the dam, and it generates high concentrations of nutrients, furthermore a drastically decrease the oxygen concentration which sometimes turn up anoxic conditions.

The third wetlands, the Barbate salt marsh (figure 3), plainly show a nutrient decrease from the head moving downstream. This concentration gradient is because on both banks, former salt marshes are now plains used for agriculture and stockbreeding, drained with a network of artificial channels that flow, in the most cases, into the

river. As we approach the mouth stations, nutrients decrease through dilution processes. We detected strikingly high ammonium concentrations, higher than those found in the aforesaid estuary, indicating the importance of remineralisation processes.

In Sancti Petri sound (figure 4), the higher nutrient concentrations were particularly noteworthy could be particularly interesting the raised nutrients concentrations close to the point where untreated wastewater from the city of San Fernando is dumped (station 3). The nutrient concentrations at this point are three times higher that at station 1. This progressive drop in concentration to the south of the sound's mouth is due to dilution processes. The high relative concentrations of ammonia, the majority specie of nitrogen, indicate the importance of diagenetic processes.

San Pedro River, like Sancti Petri sound, shows a decrease in nutrients as we approach the mouth. In this case, the organic matter accumulation is not due to any specific dump, but as in the Palmones River, there is a dam at the head. Again, the majority nitrogen specie is ammonia, indicating a major benthic regeneration of organic matter, typical of shallow seawaters.

DISCUSSION

The most striking aspect of these results is the wide variability in the data, since each of these five systems has its own characteristics, influenced by various factors, e.g. hydrodynamics, the composition of the river basin, ground uses, and anthropogenic impact.

Each wetland area has a particular hydrochemistry, as shown in figure 6. There are systems with fluvial predominance, tidal ones, and transitional environments where a gradient between the preceding ones can be observed.

Regarding nutrient results, we found that estuaries with a fluvial predominance (Guadiaro and Palmones) are relatively stable, and remineralisation hardly occurs. When tidal influence increases, ammonia is the prevailing nitrogen specie. This finding shows that they are unstable environments, with major benthic regeneration.

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