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Tidal nitrogen and phosphorus exchange in the Palmones River estuary (Algeciras Bay, Cadiz)

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ABSTRACT

The estuary of the Palmones River is a shallow fluvial catchment area, which had suffered major hydrodynamic changes over the last decade related to the construction of a dam. The estuary acts as a nutrient sink, and its catchment area shows high eutrophication (Pérez-Lloréns, Fernández and Niell, 1989; Clavero, Niell and Fernández, 1997).

Nutrient concentration, salinity and evolution of current speed were monitored at the mouth of the estuary during a complete tidal cycle in the spring of 1997. The authors found strong water-column stratification, which enabled them to determine the input and output estuarine fluxes, using a two-box model. The deepest water mass, with a relatively constant composition, is responsible for the nutrient input into the estuary. Surface waters export nutrients to adjacent coastal zones, although this phenomenon has an obvious seasonal component. Net balance reveals a silicate, phosphate and ammonia output and frequent nitrogen forms (nitrite and nitrate) inputs.

Key words: Estuary, tidal exchange, nutrients, Palmones River estuary.

RESUMEN

Intercambio de nitrógeno y fósforo con las mareas en el estuario del río Palmones (bahía de Algeciras, Cádiz)

El estuario del río Palmones es una cuenca fluvial de escasa profundidad que, en la última década, ha sufrido un represamiento, originando importantes cambios en su hidrodinámica. El estuario se comporta como un sumidero de nutrientes y su cuenca experimenta una alta eutrofización (Pérez Lloréns, Fernández y Niell, 1989; Clavero, Niell and Fernández, 1997).

Se ha seguido la evolución de la concentración de nutrientes, salinidad y velocidades de corriente en la desembocadura del estuario durante ciclos de marea completos en la primavera de 1997. Debido a la intensa estratificación encontrada en la columna de agua, los flujos de entrada y salida del estuario se han cuantificado mediante un modelo de dos cajas. La masa de agua más profunda, con una composición relativamente constante, es responsable de una entrada de nutrientes en el estuario. Por el contrario, las aguas más superficiales exportan nutrientes a otras zonas adyacentes, aunque este fenómeno tiene una clara componente estacional. El balance neto pone de manifiesto una salida de silicato, fosfato y amonio y una entrada en el sistema de formas asiduas de nitrógeno (nitrito y nitrato).

Palabras clave: *Estuario, intercambio mareal, nutrientes, estuario del río Palmones.*

INTRODUCTION

From a chemical point of view, estuaries are very interesting areas, because they are the route of access for numerous substances, and also due to the intensive gradients generated therein by the compositional differences between seawater and fresh water.

Generally, rivers along the southern coast of Spain are small catchment areas, and all along this coast there are small tidal estuaries with a high level of human activity (Peralta, 1996). The Palmones River and its estuary drain into Algeciras Bay, near the Straits of Gibraltar (figure 1).

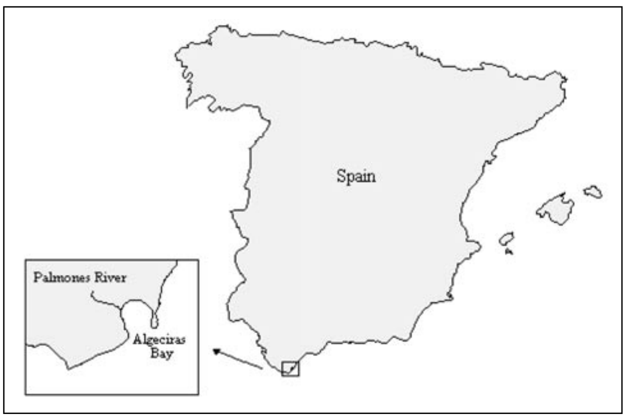

Figure 1. Map of the study area

Because of a dam built on the higher part of the Palmones River in 1985-1986, water flow and current-speed of the river have been reduced. One consequence of the decreased water flow was that the river's capacity to dilute the discharge of urban and industrial effluents also fell. The drop in current-speed favoured particulated material sedimentation, having an impact on nutrient dynamics, as well (Valiela and Teal, 1979; Clavero, Niell and Fernández, 1997). These effects were intensified by the severe 1993-1995 drought.

In 1984, the estimated surface covered with estuarine water masses was four times greater than the present-day surface area. From 1989 to 1994, a substantial increase in C and P contents in sediment was observed. Total phosphorous accumulation was 6 times greater than in 1989, and the organic matter rate increased from 3 % to today's value of 10 % (Clavero, Niell and Fernández, 1997). Likewise, in 1993 the estimate of the tidal exchange of soluble reactive phosphate showed an input of 3.26 g s^{-1} with each tidal cycle (Clavero, Niell and Fernández, 1997). We can assume that the estuary acts as a phosphorous sink.

The present paper attempts to quantify the output and input fluxes in the estuary during a typical spring scenario, and to make a general characterisation of nutrient exchange in the estuary.

MATERIALS AND METHODS

Samples were collected every hour at two different depths: 50 cm from the surface and 50 cm from the bottom, during two complete tidal cycles during the spring of 1997. Current-speed was quantified with a portable currentimeter (STS Oceanspace Ltd. DNC-3A). Measurements were taken in the middle of the estuary mouth, at the two depths noted above. Salinity was measured with an induction salinometer (Beckman, RS-10), equipped with an automated temperature control.

Dissolved oxygen concentration was determined with potentiometric titration (Metrohm 670) based on the classic Winkler method.

Nutrient analyses were performed with a segmented continuous auto-analyser (Bran+Luebbe, TRAACS 800), adapted to the automated methods of Grasshoff, Ehrardt and Kremling (1983).

Total nitrogen and phosphorus concentration was determined by measuring the nutrient concentration in UV radiation samples (Metrohm 705 UV Digester). Particulated N and P were calculated as the difference between the total amount and soluble inorganic species concentration.

The existence of chlorophyll-*a* was determined by a Perkin Elmer (Lambda 11) spectrophotometer using Lorenzen's equations (Strickland and Parson, 1968).

RESULTS AND DISCUSSION

Our findings on temporal evolution of salinity (figure 2) were quite different between the bottom and the surface. Whereas on the bottom it was relatively constant, with values close to 36 ups, on the surface there was a wide variation associated with tidal cycles. During low tide, salinity differences (up to 18 ups) were observed in only 2.5 m of depth.

This estuarine water-mass stratification enabled us to quantify the species exchange at the mouth of the estuary using a two-box model. The surface box thickness was 1 m, whereas the bottom thickness

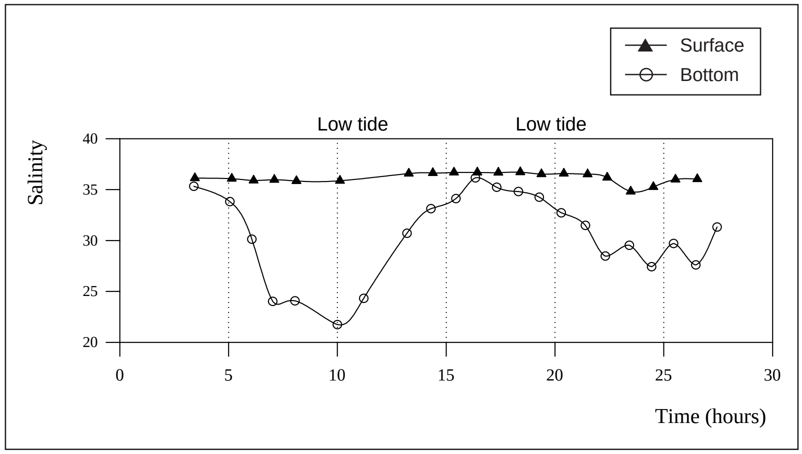

Figure 2. Temporal evolution of salinity during two complete tidal cycles at the mouth of the estuary at two different depths: surface and bottom

depended on the tidal moment, having an average value of approximately 1.5 m.

To determine instant fluxes, we used the equation F = C V S, where F is the instant flux for a certain nutrient in one of the two boxes, C is the instant nutrient concentration, V is the current-speed, and S is the box section at that moment.

Current-speed evolution over a complete tidal cycle is shown in figure 3. Values at the surface and the bottom are similar, so average values have been used to calculate the fluxes.

Figure 4 shows the evolution of the phosphate and the inorganic nitrogen instant fluxes. Positive values mean estuary output and negative ones correspond to nutrient input. Inorganic N fluxes are more intensive than phosphate fluxes.

There is a striking cyclical variation associated with tides, with dissolved N and P outputs during low tide and inputs during high tide.

Surface fluxes are higher than bottom ones. As a net balance, there are silicate, phosphate and ammonia exports, as well as nitrite and nitrate inputs. A global balance of total inorganic nitrogen (as a sum of ammonia, nitrite and nitrate) shows an output from the estuary to the bordering coastal zones.

These nitrogen forms' interconversion in shallow coastal systems have been described by several authors, who observed nitrate transformation onto ammonia and particulated nitrogen, which are both exported to coastal zones with tides.

Table I shows average inputs and outputs of chlorophyll-*a*, particulated N and P fluxes and the global balance. There are also chlorophyll-*a* and particulated material exports. These findings support the hypothesis proposed in this paper: the Palmones River estuary acts as a productive system, able to export N and P to near coastal zones. We observed that for both, chlorophyll and particulated material, output fluxes are greater than input ones.

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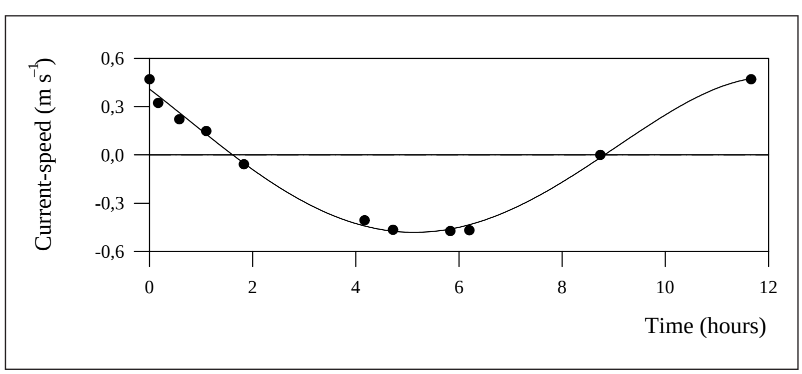

Figure 3. Current-speed evolution (m s^{-1}) during a whole tidal cycle at the mouth of the estuary. The values represent the average of the values mesured at different depths

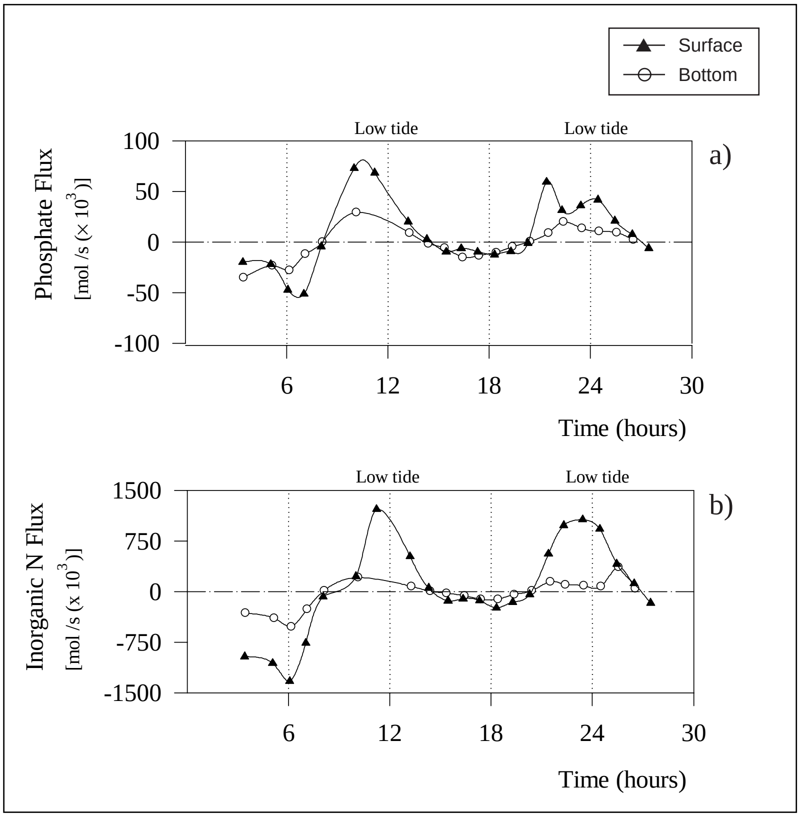

Figure 4. Temporal evolution of nutrient instant fluxes (mol/s (× 10^3)) during two tidal cycles at the mouth of the estuary at two different depths: surface and bottom. (a): phosphate; (b): inorganic nitrogen

Tabla I. Chlorophyll-*a* and particulate material estimated estuarine tidal fluxes. PP and PN mean particulated phosphorus and nitrogen, respectively

	Input	Output	Net balance
Chlorophyll-*a* (mg s^{-1})	56.9	78.0	21.0
P.P. (g s^{-1} × 10^3)	26.4	29.8	3.4
P.N. (g s^{-1} × 10^3)	593.2	932.2	339.0

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