MORPHOLOGY AND PHYSICAL PARAMETERS OF THE CLAROMECÓ CREEK ESTUARY, ARGENTINA.

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ABSTRACT

The Claromeco river is located in the southeast of the Buenos Aires province. The estuary of the Claromeco river is a coastal plain one. An important resort area is associated to the estuary. The main economical activities of the coastal area are fishing and tourism. There are some coastal management programs related to the estuary. One of them is to construct a marina. Unfortunately, there are not previous investigation done in this estuary, therefore the aim of this research is to begin the preliminary studies of the physical characteristics of the Claromeco estuary. At each station, vertical profiles of velocity, salinity, temperature and suspended sediment were obtained during the whole tidal cycle. The turbulent mixing due to tides, wind and the low depth of the estuary originates an homogeneous water column. The suspended sediment transport is low even during ebb tide. There is a significant spatial salinity distribution across the river section of 6.4 in 50 m distance between the north the center stations during the flooding. Being the central station the one that presented the highest tides. There is no a significant salinity spatial variation during ebb. The mean water temperature was 21.5º C with vertical temperatures gradients of 0.88ºC/m in the north station.

INTRODUCTION

An estuary is a partly enclosed coastal body of water that stretches as far as the actual limit of tidal influence, and in which seawater - entering by means of one or several connections with either the open sea or a coastal body of salt water- is significantly diluted by fresh water from soil drainage. In addition, it can support euryhaline species during part or the whole of their life cycle (Perillo, 1995). The formation of estuaries is regulated by several factors, notably the climate, the type of banks and their lithology, the tidal level and the diffusive forces of the sea.

The areas of transition between the fluvial and marine environments constitute complex regions of great importance to man. First, their estuarial ecosystems present waters populated by many marine species which are valuable food resources. Second, they
harbour ports for the import and export of goods and, last but not least, their beaches and resorts provide excellent recreation.

Owing to the importance of these environments, there exists extensive hydrographical research on estuaries in developed countries. As regards Argentina, there has been an increasing interest in the issue of late. Although about ten primary estuaries and as many again of a secondary nature flow into the Atlantic, there are relatively few hydrographical studies on them. The most widely researched are those of River Chubut (Perillo and Piccolo, 1989; Perillo et al. 1995), River Plate (Guerrero et al., 1997; García and Vargas, 1998; López Laborde and Nagy, 1999; Framiñan et al., 1999), Bahía Blanca (Perillo and Piccolo, 1999; Piccolo and Perillo, 1999; Gómez et al., 2000; Perillo et al., 2000; Perillo et al., 2001), River Quequén Grande (Campo and Piccolo, 1996, 1998,Perillo et al., 2003) and River Quequén Salado (Marini and Piccolo, 1997a,b).

Research undertaken on the area referred to in this paper- widely-known as " Fishermen's Paradise " for its rich and diverse ichthyofauna- is scarce, particularly in the field of estuarial hydrography. Worth-mentioning is the study conducted by Fangau(1990) which focuses upon its fauna. In addition, other authors have carried out granulometric analyses of the Claromecó beaches (Isla et al., 2001), although not in the actual estuary but on the adjacent coast.

The objective of this research is to analyse the hydrographical characteristics of the Claromecó Creek Estuary (Figure 1). This is the first of several investigations which will aim at studying the estuary in full. An important resort area is associated to the estuary. The main economical activities of the coastal area are fishing and tourism. There are some coastal management programs related to the estuary. One of them is to construct a marina.

**MATERIALS AND METHODS**

A bathymetrical study of the creek was carried out from its mouth to the inner sector of the estuary. Transverse sections were cut every 20m along its course. The study was completed with longitudinal sections of the banks. Moreover, in the outer area sections both perpendicular and parallel to the banks were obtained every 50 and 20m, respectively. A 4.5m-long inflatable dinghy as well as an echo sounder were used to conduct the bathymetrical study. The bathymetry was set with a GPS in differential mode. In order to determine the hydrographical characteristics of the estuary, salinity and temperature were measured along the course.

These parameters were estimated using an inflatable boat and a mini CTD. The latter was connected to a portable computer by means of an interface, thus enabling a continual digital registration. A vertical section was performed at each station up and down the creek. This procedure was followed at both rising and ebb tide to establish the penetration of salt water in the creek. Measurements were made at seven different stations along the course.

Temperature, salinity, concentration of sediments in suspension, speed and direction of currents were measured along a transverse section of the creek-1.7km away from the estuary mouth in the vicinity of the bridge connecting Claromecó with the residential district of Dunamar (Figure 1). Three measurement stations were set, two of them close to the creek banks and the remaining in the middle of the course.

Every station obtained constant profiles of salinity, temperature and concentration of sediments in suspension. The latter was determined by means of an OBS which measures turbidity. The Central Station gauged currents at three different depth levels along the course (0.30m, 1.00m and 1.90m) using a current meter. Measurements were continually taken during thirteen hours of the tide cycle. The stations were named Northern (38° 51' 13" S- 60° 05' 01" W), Center (38° 51' 14" S- 60° 04' 59" W) and Southern (38° 51' 13" S- 60° 04' 57" W) according to their geographical
In order to determine the effect of the tide on the creek, a limnimeter-phreatometer was placed in the innermost part of the area studied (first rapid) and a mareograph was positioned 1.5 km away from the limnimeter at the mouth of the estuary. Both gauges were used to take continual measures during two days.

RESULTS

The Claromecó Creek flows into a small coastal plain. The estuary is 1.9km long and a maximum 3.2m deep. Whereas at its mouth the estuary is 88m wide and 1.5m deep, it is 105m wide and 3m deep in the vicinity of the bridge (Figure 2). The internal limit of the estuary is located in the area of the second rapid (38° 52' S- 60° 05' W), where depth is below 1m at low tide and the course never exceeds a 40m width. The creek bed is sandy. The coastal area adjacent to the estuary presents a maximum depth of 9m, 350m off the coast. There are depressions of up to 4m in depth between the 3 and 4m isobaths. The navigation of ships with a shallow draft is restricted due to the fact that the creek never exceeds 3m in depth when it meets the sea, even when measures are taken 50m perpendicular to the beach. Water temperature is 2.5º above that of nearby resorts (Atlas Total, 1984). The beaches present fine sands and are rich in clam banks.

The dynamics of the estuary are important due to the two processes to which it is exposed. On the one hand, the southwesterly-northeasterly currents from the littoral drift which tend to deviate its last stretch. On the other hand, there is the significant amount of water derived from freshets. Equally relevant are the northern and eastern winds (with gusts of up to 104km/h) which blow on the beaches adjacent to the estuary.

At the mouth of the creek there is a jetty that controls the flowing of the creek into the sea. The characteristics of the bottom restrict the navigation of ships used for low-scale fishing, the main economic activity of Claromecó. On both banks of the creek there are wandering dunes whose height ranges from 1 to 3m. Those on the left bank present dense vegetation, while those on the right bank feature non-vegetated areas. The predominant species are pampas grass (Cortaderia selloana), Myriophyllum sp., and bushes (Tamaricaceos) which are up to 2 m in height.

The Claromecó Creek Estuary presents a mixed semidiurnal regime of tides, with two high tides and two low tides of different height occurring every 24 hours. Examples of tide waves registered at two different stations are shown in Figure 3. Both waves describe the same trajectory, but the limnograph of the inner estuary shows a higher tidal level at the second
high tide. Thus, the estuary could be described as hypersynchronous. Moreover, owing to the distance existing between both measuring devices (1.5 km), the time elapsing from the end of the ebb tide to the beginning of the flow is out of step with the tide at the mouth of the estuary.

Figure 4
Longitudinal distribution of salinity in the estuary

Figure 5
Vertical distribution of salinity in the water column

Figure 6
Vertical profiles of salinity at the North and South stations.
Salinity and Temperature

The longitudinal sections cut at low and at high tide prove that there is a significant influence of the sea upon the creek at rising tide. The distribution of salinity in the estuary is shown in Figure 4. High salinity values are registered on the surface almost as far as 1 km up the estuary.

From that point onwards and as the headwaters approach, isohalines present a salt ridge which penetrates up to 1.8 km into the bed. The difference in salinity between the headwaters and the mouth is 12. Taking into account the salinity values under 6 registered at the mouth, the fresh water from the creek exerts a strong influence upon the system at low tide. The mixing process in this estuary is restricted to a thin transitional layer between the fresh water at the top and the salt water ridge at the bottom.

The interrelation between fresh water and salt water results in a course with an increased salinity from the surface to the bottom. The limit of both layers—originating from such an interaction—appears when the salinity gradient increases significantly. The gradient will vary according to the stage of the tide cycle, thus values of up to 7.8/m and 0.7/m were registered at rising and ebb tide, respectively (Figure 5).

As the tide ebbs the creek exerts a greater influence, creating a single homogeneous layer. This layer is made up of the waters from the Claromecó Creek. The shallowness of the estuary at ebb tide makes the difference in salinity minimal.

At the second high tide, there is a significant stratification of the watercourse with a salinity variation of up to 16 between the surface and the bottom. This parameter registers its highest values at high tide, with a maximum of up to 23 at the bottom and of up to 4 on the surface (Central station). Therefore, vertical profiles show a salinity close to 1 on the surface and higher values near the bottom (Figure 6).

The distribution of salinity presents a similar pattern at all stations (Figure 7). Although salinity does not exceed 9 at the first high tide and ebb tide, there are important gradients at the second high tide when it increases at the bottom. The gradients registered are 13.6/h at the Northern station, 14.8/h at the Central station and 14.3/h at the Southern station. This variation may be due to the fact that high tides differ in
height. Thus, the higher the tide, the greater the salinity gradient.

The distribution of water temperature along the course is shown in Figure 8. At rising tide temperature ranges from 20.3 to 21.5°C at the mouth and headwaters, respectively. At ebb tide, it oscillates between 21.1°C at the mouth and 21.9°C in the inner part of the estuary. The registered temperatures reveal, on the one hand, the influence of the sea at rising tide and, on the other hand, the predominance of fresh water at ebb tide, made evident by the rise in water temperature.

Temporal variation in water temperature, associated with the interaction between fresh water and salt water, presents special characteristics in this estuary. Figure 9 shows the temperatures obtained at the three sampling stations. At the Northern station, temperatures as low as 21.1°C and 21.9°C were registered at ebb and flow, respectively. Meanwhile, the Center station presented values between 20.3°C and 21.9°C at ebb and flow, respectively, and the Southern station values gauged at the same times oscillated between 20.4°C and 21.8°C.

Temperature profiles show that the watercourse is vertically homogeneous. Owing to shallowness all stations present a 1.2°C vertical gradient. Moreover, water temperature behaves similarly at the three stations, revealing a strong fresh water influence on the estuarial system. At the end of the period, there is a notable variation in temperature, which exceeds 1°C at every station. This event occurs after the second high tide, when the waters reach their highest level.

**Sediment in suspension**

The samples of sediment in suspension analysed at every station show a predominance of fine particles. The granulometry corresponding to sediment in suspension for each station is shown in figure 10. The sediment found at the Northern station is 31% clay, 51% silt and 18% sand. Meanwhile, the sediment found at the Center and Southern stations is 52% silt, 29% clay and 19% sand for the former, and 27% clay, 57% silt and 16% sand for the latter. Sediment can be
classified as silty clay. It has a high percentage of silt made up of very fine grains. In all samples, values corresponding to fine-grained sand are notably lower than those of very fine sands, particularly at the Central station. Silt, ranging from fine and medium to very fine, increases in importance at the Southern station.

Four nuclei of sediment in suspension are observed at the Northern station (Figure 11). Three of them are located near the bottom, and the remaining one can be seen along the whole watercourse. The maximum sedimentary concentration is 169mg/l and is registered both at the bottom at the end of the ebb, and on the surface at the beginning of the flow. Towards the end of the flow, there is sediment in suspension at the bottom, the maximum reaching 170mg/l.

The Center station reveals three zones of high sedimentary concentration. The most important nucleus appears at the bottom at the beginning of the flow with a concentration of up to 125mg/l. The remaining nuclei are also observed at the bottom at about 3 or 5.30 p.m., with concentration values no higher than 75mg/l.

As regards the Southern station, the highest concentrations are registered at mid ebb tide (in the middle of the watercourse) and at low tide (near the bottom), with a maximum 155mg/l. At flow concentration values are no higher than 70mg/l. Significantly, all three stations show the maximum concentration of sediment in suspension at the same stages of the tidal cycle and, what is more, it is almost always observed at the bottom. While the Northern station presents the greatest values - over 190mg/l - concentrations are never higher than 160mg/l.

**Currents**

The speed of the currents, measured at three different depths at the Central station, is similar both on the surface and at the bottom of the watercourse throughout the tidal cycle. Naturally, according to the profiles, the highest speeds were observed on the surface and at ebb and flow, while the lowest were registered at low and high tide. Owing to the shallowness of the estuary and the tidal amplitude, currents can be classified as reversible. The speed of the flow is greater than that of the ebb and consequently, it lasts shorter.

Speed variation for the longitudinal component (u) during the tidal cycle is shown in figure 12. This component is the dominant, and its values represent almost 75% of the speed vector. At low tide speed decreases to zero with a delay of an hour due to the influence of the creek. Later on, it increases significantly with maximum speeds of 0.52 and 0.49 m/s at ebb and flow, respectively. Transverse speed registers its lowest values at mid rising tide. The maximum value being 0.25 m/s at flow and the minimum, 0.22 m/s at ebb.

**Discussion**

Estuarial depth and width increase from the headwaters to the mouth. Fishing boats with a shallow draft are forced to sail parallel to the coast due to the characteristics of the bottom at the estuarial mouth.

The fluvial discharge modifies the physiognomy of the estuarial mouth. When the creek level increases as a result of rainfalls above 100mm in the Mid-Basin,
the estuarial mouth shifts to the eastern sector. The force of the waters contributed reveals rocky salients at the creek mouth. Being more visible at low tide, this change in the profile of the course should be considered by fishermen to avoid damages to the hulls. Another serious consequence of the fluvial discharge is that an important freshet of the creek may cut off the jetty which controls its flowing into the sea, thus creating a secondary mouth.

As regards tidal influence upon the estuarial system, it stretches 2km upstream as far as the first and second rapids. Tidal propagation in the interior of the estuary renders it hypersynchronous. Meanwhile, tidal amplitude increases upstream, where the course of the creek decreases in width and water level rises significantly at low tide. The tide is mixed semidiurnal with two high tides and low tides a day, each of different height. The mean tidal amplitude is 0.98m and corresponds to the microtidal classification.

The mixing process in the estuary is restricted to a thin layer between fresh water at the top and the salt water ridge at the bottom. The difference between the two masses of water leads to their separation. The depth of the interface decreases slowly towards the end of the estuary. Fresh water moves outwards on the estuarial surface at low tide when it exerts its major influence. Likewise salt water influence is made evident by the salt water ridge which penetrates as far as 1.8km into the creek bed at the second high tide. In addition, it is at this stage of the tidal cycle that the inner sector of the estuary reaches its greatest depth (up to 3.2m), and that salt water presents its maximum values.

Concerning sediment in suspension, the highest concentration observed is 195mg/l. The material found in the estuary is silty clay and, therefore, constitutes fine sediment. As a result of the speed presented by the course, which dissipates its energy in the inner estuary, the largest deposits of sediment are found at the bottom of the section. Particles are reduced and the concentration of sediment in suspension does not exceed 200mg/l. It is precisely due to reduced turbidity that some of the most highly prized fish varieties are found in these waters, e.g. Pachyrus paranaensis (a kind of river maigre), Odontesthes bonariensis (a type of silverside), Achirus sp. (a kind of sole) and Menticirrhus americanus (widely-known as "burriqueta").

According to the geomorphological features of the mouth of the Claromecó Creek, the estuary can be classified as a coastal plain one. Morphology exerts an important control on the transport of sediments and, since there is both a relatively reduced contribution of fluvial waters and a small tidal level, it conditions the processes undergone by the inner estuary.

The Claromecó Creek estuary- characterized by its low banks, its shallow depth and a reduced tidal level- presents significant and balanced processes of erosion and sedimentation. The water level of the creek is under 3m3/s and conditions the internal processes of the estuary.
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