Abstract
In the spring of 2003, 240,000 m$^3$ of sand were dredged from the main channel of the lower Oka estuary (Urdaibai Reserve of the Biosphere) and dumped on the southern area of Laida beach located at the estuary mouth. After few months, strong erosion of the deposited sediments occurred as a consequence of the northwards migration of the final meander of the main estuarine channel before it reached the estuary inlet. At the same time, the estuarine inlet abandoned its original position near the rocky western margin and migrated eastwards cutting and eroding the sandy ebb delta (Mundaka sand bar). This caused a change in the way the incident wave broke as it reached the shallow water of the ebb tidal delta and beach and made surfing impossible under the same optimal conditions previously enjoyed due to the production of a wave that gradually broke from right to left as it reached shallow water, the so called “Mundaka left wave”. As a consequence, the Billabong Pro surf championship was cancelled in 2005.

This paper describes the results obtained during a study of the outer estuary carried out during the period May 2005-April 2006 to characterize the processes operating on the most dynamic area of the estuary throughout the year and to evaluate the influence that the anthropogenic activities in the estuary had on the wave characteristics.

No corrective measures were taken in the outer estuary during the study period and the environment recovered its normal morphological features naturally. This natural restoration it is hoped will be more stable, long lasting and reliable to ensure the continuing future of the “Mundaka left wave”.

Keywords: morpho-dynamical study, ridge and runnel, tidal currents, sand transport, wave action, surf activities, lower Oka estuary
1. Introduction

El estuario de Oka se encuentra en la costa oriental del puerto de Bilbao. Desde 1984 ha sido declarado como una Reserva de la Biosfera por la UNESCO. El estuario es conocido por la calidad de su olas que son ideales para el surfing, particularmente la famosa “ola izquierda de Mundaka”. De hecho, la falta de medidas correctivas ha llevado a una reducción de la calidad de las olas en la zona exterior del estuario.

2. Methods and Results

2.1. Wave climate

Los datos utilizados para caracterizar el régimen de olas externo fueron proporcionados por el ODIN programa (SMC) y se obtuvieron del puerto de Bilbao. Las olas provenientes del noroeste pueden ser agrupadas en dos tipos: ondas de “swell” con periodos largos, y “sea” olas con periodos cortos. Todas las demás direcciones son olas con patrones de propagación que sólo producen olas de “sea” tipo.

Hence the name of “Mundaka left wave” as when viewed from the sea it breaks progressively from right to left. The most favourable conditions to form breakers suitable for surfing occur around low tide due to the smaller depth of water over the sand bar. Essentially, the formation of the famous “left wave” requires moderate to intense wave conditions (typical of the autumn-winter), low tide (if possible during spring tides) and southerly or westerly winds.

The quality of the surfing depends upon changes of the sand bar morphology over the year, with the optimum conditions occurring immediately after the summer, then deteriorating slowly throughout the winter.

The attraction of large numbers of surfers each year is an important source of income for the surrounding communities and, consequently, there was much local concern because of the loss of wave-quality for surfing. A morphodynamical study of the Oka estuarine mouth was carried out with the purpose of establishing the factors controlling the pattern of wave-breaking in the area and to discuss possible corrective measures to adopt in case environmental conditions changed and did not return quickly to the normal situation (Cearreta et al., 2006).
Fig. 1.- Location of the study area and of the different elements of the estuary mouth.
Fig. 1.- Localización del área de estudio y diferentes elementos constitutivos de la desembocadura del estuario.

Fig. 2.- Location of dumping areas of historical dredgings in the lower estuary.
Fig. 2.- Localización de las zonas de vertido de los dragados históricos en la mitad inferior del estuario.
Fig. 3.- Study area and sedimentary processes involved between June 2003 (sand dumping)-May 2005 (beginning of this study).
Fig. 3.- Zona de estudio y procesos sedimentarios involucrados entre Junio 2003 (vertido de arena)-Mayo 2005 (inicio de este estudio).

Using the seasonal data from the Bilbao buoy for the period 1990-2003, Cearreta et al., (2006) observed that the wave climate can be divided in two different periods. In the summer, sea waves are dominant with a maximum period of approximately 9 s (periods higher than 10 s do not occur more than 25% of the time); waves are characteristically low, with significant heights higher than 2 m occurring only 10% of the time. However, in winter, long period swell is dominant, with maximum periods around 13 s with waves of periods shorter than 10 s occurring less than 20% of the time. These waves are usually high, with heights exceeding 2 m more than 50% of the time. In spring and autumn intermediate values occur.

The local wind intensity and direction, during the period May-October, are essentially from the north and from the south, reaching average daily velocities of 1-2 m/s. Occasionally within this period, isolated peaks with velocities up to 6 m/s occur. On the other hand, the period November-April is characterized by predominance of northerly winds with an average daily velocity of around 4 m/s or higher; the maximum monthly values can reach up to 10 m/s (Cearreta et al., 2004).

2.2. Morphological evolution of the outer estuary

Eleven monthly bathymetric surveys were carried out on the outer parts of the estuary (May 2005-April 2006) using the bottom tracking tool of an Acoustic Doppler Current Profiler (ADCP Winriver RDI 1200) with a Trimble GPS located on board a small vessel (4 m long). Data were corrected using the nearby Bilbao tide gauge record and bathymetric maps were produced using the Surfer 8 software. Additionally, topographic measurements of the Laida beach intertidal area were made every two months using a Leyca 5010 total station, located on several fourth-order points around the beach, in order to complete the bathymetric picture.

Under summer conditions, on the low intertidal area north of Laida beach, there is a continuous migration to the southwest (N220º) of various sand bars (Fig. 4). These ridges are the result of sand being transported from the northeastern bay area to the beach and estuarine inlet. In this way, a typical summer beach profile, characterized by ridges and runnels in the intertidal area is created. The formation of a steep slope on the front of the berm separating the intertidal and supratidal sections of the beach was also characteristic during this period.

The new “anomalous” inlet at the eastern side of the estuary which had been generated by the sandy accumulation at its mouth (Fig. 3) disappeared between July and August 2005 due to both the landward migration of the intertidal sand ridges and to the sand transport produced by the ebb currents. These processes reinforced the development of the Mundaka sand bar and returned the inlet...
Tabla 1.- V olumen de arena erosionado en el margen sur de la playa de Laida.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Total erosion (m$^3$)</th>
<th>Average erosion (m$^3$/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 2001-March 2003</td>
<td>52,500</td>
<td>3,500</td>
</tr>
<tr>
<td>June 2003- December 2003 (post sand dumping)</td>
<td>65,500</td>
<td>11,000</td>
</tr>
<tr>
<td>December 2003-June 2004</td>
<td>33,000</td>
<td>5,500</td>
</tr>
<tr>
<td>June 2004-March 2005</td>
<td>51,400</td>
<td>5,700</td>
</tr>
<tr>
<td>March 2005-May 2005</td>
<td>11,000</td>
<td>5,500</td>
</tr>
<tr>
<td>May-September 2005 (summer period of study)</td>
<td>35,700</td>
<td>7,000</td>
</tr>
<tr>
<td>September 2005- April 2006 (winter period of study)</td>
<td>32,800</td>
<td>4,700</td>
</tr>
</tbody>
</table>

Table 1.- Sand erosion on the southern part of Laida beach (December 2001-April 2006).

2.3. Temporal evolution of southern area of Laida beach

Analysis of the temporal evolution of the southern landward margin of Laida beach has been divided into four different time periods. Firstly, the situation previous to the sand dumping (December 2001-March 2003); secondly, the period after the sand dumping (June 2003-May 2005); thirdly, the summer period of this study (May-September 2005); and finally, the winter period of this study (September 2005-April 2006). Comparison of the topographic measurements obtained at the beginning and the end of these periods allows a calculation of the changes of sediment volume with time (Cearreta et al., 2006).

All these periods were characterized by erosion in this area although sediment depletion was quantitatively different during each analyzed time interval (Fig. 6). Before the sand dumping, erosion was unimportant and was concentrated on the landward and northwestern areas of Laida beach close to the inlet of the estuary as a consequence of the lateral migration of the final meander promoted by tidal currents (Table 1). Since the last dumping of sand, the volume of eroded sediment per time unit increased enormously (11,000 m$^3$/month) and introduced a huge amount of sand into the mouth of the estuary; this was deposited in the inlet closing it and modifying its normal disposition (Fig. 3). Since then, the rate of erosion has decreased significantly (Table 1).

During the period of study, this erosion continued during the summer although it became progressively less during winter, but without reaching the levels of the minimum erosion rates recorded previous to the last sand dumping in 2003 (Table 1, Fig. 6).

2.4. Waves and currents in the outer estuary

A total of eight campaigns of current and wave measurements were carried out in the estuary mouth, using three 808 Valeport currentmeters (4 campaigns in summer, May 2005) and 730D Valeport currentmeters (4 campaigns in winter, January 2006). These currentmeters are electromagnetic instruments equipped with sensors to measure current velocity and direction, conductivity,
Fig. 4.- Monthly bathymetries of the Oka estuary mouth. May, July, September, October and December 2005, February and April 2006 include also topographic information of the intertidal areas. Solid white line represents LWM (low water mark, 0 m) and dashed black line represents HWM (high water mark, 4 m). Blank areas were unsurveyed.
Fig. 4.- Batimetrias mensuales de la desembocadura del estuario del Oka. Los meses de Mayo, Julio, Septiembre, Octubre y Diciembre de 2005, Febrero y Abril 2006 incluyen además la información topográfica de las zonas intermareales. La línea negra continua representa el NB (nivel de bajamar, 0 m) y la línea blanca discontinua representa el NP (nivel de pleamar, 4 m). Las zonas blancas no fueron estudiadas.
Fig. 5.- (this page and the next one) Detailed monthly bathymetries of the Mundaka sand bar (years 2005-2006). Blank areas were unsurveyed.

Fig. 5.- (esta página y la siguiente) Detalle de las batimetrías mensuales en la barra arenosa de Mundaka (años 2005-2006). Las zonas blancas no fueron estudiadas.
temperature, turbidity and pressure (Fig. 7).

Instruments were located at different positions, in an attempt to cover completely the estuarine mouth area and the possible variations on both tidal range (spring, intermediate and neap tides) and longitudinal and transversal morphological elements of the environment.

Under summer conditions, maximum currents were observed close to the west margin of the estuary mouth (Mundaka port) during ebb tide and low water. The delay of the tidal wave during the ebb was approximately 1 hour on the Mundaka sand bar area. These currents exceeded 0.8 m/s during spring tides and decreased rapidly east-
ward, being almost zero on the low-tide terrace of Laida beach. In the area where the anomalous inlet was located during the winter of 2004 the currents were less than 0.4 m/s during the ebb. On the contrary, during the flood tide current directions were very uniform throughout the whole area and were directed towards the inlet, increasing their values from 0-0.1 m/s (on the northwestern margin) to 0.3-0.4 m/s (on the intertidal area of Laida beach), and being practically zero around high water (Fig. 8).

Under winter conditions, the maximum ebb tide and low-water currents flowed out of the inlet, in a seaward direction and were converged along the external parts of the low-tide terrace. These currents attained 0.7 m/s. On the contrary, during the flood tide current directions were very uniform throughout the whole area and were directed towards the inlet increasing from 0.1-0.2 m/s (on the northwestern margin) to 0.2-0.3 m/s (on the southwestern shallower areas), and were practically zero around high water (Fig. 9).

2.5. Currents and sedimentary transport in the estuary inlet

Transverse transects under spring and neap tide conditions during both summer (May 2005) and winter (November 2005) periods were carried out in the internal parts of the inlet using ADCP and GPS instruments. The ADCP allows the measurement of current direction and velocity in the water mass by the Doppler effect. At the same time, a bottom tracking of the inlet was performed...
and the amount of sediment transported in suspension and near the bed within the water mass was qualitatively estimated by back-scattering techniques. Sediment samples were collected using a Niskin bottle (capacity: 1.8 l). It was observed that the sediment in the water column was mainly sand. Furthermore, the analyzed backscatter profiles clearly showed that this sediment, both the incoming and outgoing, came from the eastern margin of the channel close to Laida beach. Bearing in mind that a great amount of sediment is transported through the inlet channel as bed-load and also that the ADCP backscatter is unable to identify the sediment transported within the bottom 10 cm of the water column, due to ringing processes. In order to produce the backscatter calculations, the ADCP divides the vertical water column into 15-cm cells, and then calculates a current velocity and direction for each cell, assigning a value in decibels (dB) based on the amount of solids present. The addition of the backscatter values, with respect to the incoming and outgoing flows, allows a comparison to be made, in percentage terms, of the amount of sediment that enters or leaves the estuary during a certain period of time and to assess the sedimentary balance in the inlet throughout an annual cycle. Consequently, successive transects during a complete tidal cycle (12 h and 30 min) permitted the determination of the variation and evolution of the above mentioned pa-
Fig. 9.- Distribution and velocity of currents during the winter campaign at different stages of the tidal cycle. Arrows indicate merely seaward/landward flux and they are not exact directions.

During the summer and under low water, spring tide conditions, current velocities were low; they oscillated around 0-0.7 m/s, and showed a dominant seawards direction. During flood tide lower velocities (0-0.5 m/s) occurred along the inlet margins than in the central part (1-1.8 m/s) which were the highest values obtained during the whole tidal cycle. The flow of water was clearly landwards although eddies flowing in the opposite direction were observed on the eastern margin of the inlet. During high-water, the velocities were very low, between 0-0.4 m/s, and in contrast were dominantly landwards.

Finally, during the ebb tide, velocities of 0.5-1 m/s with a clear northwesterly direction occurred. During neap tides, currents were similar except that the magnitudes of the measured parameters were lower.

During the summer period, when there was little significant wave activity, sediment transport to seawards was slightly dominant (55%) over the amount that moved landward into the estuary (45%) (Fig. 10). Probably, this export of sediment was due to the erosion of the landward part of the Laida beach-dune ridge; which provided an easily available source of sand for transport through the inlet to outside the estuary during ebb tides. When
different tidal conditions are analyzed, it is clear that during neap tides the transportation of sediment landwards into the estuary was dominant compared to the seaward outflow, whereas during spring tides sediment transport seaward out of the estuary, was dominant.

On the contrary, during the winter period, characterized by strong wave activity, sediment transport landwards into the estuary was dominant (69%) over the amount of sediment exported to seawards (31%) (Fig. 11). This was due to the erosion of the seaward flank of Laida beach which released sediment into the estuary through the inlet during the flood tide at high water. The landward movement of sand into the estuary during neap tides is very dominant as compared to the amounts moved to seawards. The same is true during spring tides but with the same process operating at a lower intensity.

3. Discussion

3.1. Temporal evolution of the bottom morphology

Sediment accumulation and erosional processes in the mouth of the Oka estuary were studied at different temporal scales (bimonthly and seasonal) by analysis of the bottom morphology at the beginning and at the end of each considered period (Fig. 12).

During the summer, on the eastern area of the open bay seaward of the Laida beach-dune barrier an eastward migration of sand ridges occurred (55,000 m$^3$, zone 1) simultaneously with erosion on the seaward parts of Laida beach (-80,500 m$^3$, zone 2). Between July-September 2005, sediment accumulated on the proximal (54,000 m$^3$, zone 3) and distal (24,000 m$^3$, zone 4) areas of the Mundaka sand bar (Fig. 12).

In contrast, during winter, important erosion occurred in the zone within the subtidal and intertidal areas of the inlet. Deposition of the eroded sediment occurred in deeper areas located further north to seawards, such as in the area below the base level of wave erosion (55,300 m$^3$, zone 1a) and also on the low-tide terrace and beach face of the eastern area of Laida beach (47,500 m$^3$, zone 1b). Intense erosion on the beach occurred in the eastern area between February-April 2006 (-115,000 m$^3$, zone 2) and in the northwestern area between November-December 2005 (-23,000 m$^3$, zone 3). Other sediment returned into the bay by the ebb-tidal currents and redirected to the distal and proximal areas of the Mundaka sand bar (94,000 m$^3$, zone 4). Erosion took place on the shallower distal area of the Mundaka sand bar and supplied sediment to the subtidal area located at its base to seaward (43,000 m$^3$, zone 4).
When the Mundaka sand bar area is analyzed in detail (Fig. 13), it is clear that the proximal (zone 1) and distal (zone 2) areas experienced sand deposition during summer (July-August 2005). Simultaneously, the inlet located at the western side of the Mundaka sand bar (zone 3) became deeper and the previous tidal delta at the mouth of the new (anomalous) inlet channel disappeared (zone 4). On the other hand, in winter (October-December 2005), sedimentation occurred on the proximal area of the Mundaka sand bar (zone 1). Sand accumulated on the break of slope of the distal area of the Mundaka sand bar (zone 2) and erosion of the distal area (zone 3) of the Mundaka sand bar occurred between October-December 2005 and January-February 2006 when important gales were experienced. Furthermore, a channel separating the proximal and distal sand bar areas deepened during October 2005-February 2006 (zone 4), and important erosion occurred at the proximal area of the base of the sand bar (zone 5).

3.2. Morphodynamical development of the outer estuary

Under summer conditions (May-October), which were characterized by the absence of gales and the presence of low intensity wave action, Laida beach received sediment from sand ridges that migrated from the northeastern area of the open bay, mostly due to the current action generated by the breaking waves and secondarily due to tidal currents. Up to three sand ridges were formed and moved landward across the intertidal area to build a beach profile and depositing a large volume of sand on the beachface, thus favoring the development of a wide berm. These sand ridges had crests with two different directions: to the south-southwest (on their west side) and to the southeast (on the east side), together with sand mega-ripples moving along the runnels, indicating the combined action of breaking waves and their variation of height and tide currents (funnelling effect). The Mundaka sand bar was fed by the tidal currents that, in the absence of gales, deepened the inlet channel and deposited the sediment on the bar after the expansion of flow (jet effect) (French, 1960; Mota-Oliveira, 1973).

During winter (November-April), as a consequence of the increased wave energy, the Laida beach was eroded and sand was transported both to the subtidal areas (Fig. 14), away from the area dominated by wave action but always within the –25 m bathymetric contour, which represents the theoretical seaward boundary of the estuarine system (Iberinsa, 1992), and to the inner estuary. This process produced a very pronounced slope on the seaward part of Laida beach. However, the intertidal zone (low-tide terrace) exhibited a flat rippled bottom morphology. Wave and tidal activity in this period eroded the Mundaka sand bar and modified its morphology.

For any one tidal cycle, during the ebb tide, tidal currents were dominant and reached their maximum inten-
sity at mid-tide. These currents transported the sand deposited by the waves, and moved it to the outer estuary and deposited it on the Mundaka sand bar. The ebb tide decelerates progressively northwards and generated a new inlet on the western margin, where the wave heights are lower. Initially (May 2005), sand accumulated within the former inlet due to the supply from the intense erosion of the dumped material landward of Laida beach. This situation changed during the study period with the deepening of the former inlet and the transportation of sand to the Mundaka sand bar in the outer estuary. At low water, the wave activity was concentrated on the Mundaka sand bar to the west and on the outer limit of the intertidal beach (low-tide terrace) to the east, eroding these areas and transporting the sediment towards the beach.

During the flood tide, the water passes through the inlet and currents are convergent and this flood supplied sand to the levee bordering the inlet on its eastern flank and together with wave action rebuilt the beach profile. Once the flooding tidal waters passed through the inlet, it expands to produce the flood-delta by the deposition of the transported sand.

Based on the wave modelling produced previously (Cearreta et al., 2006), the interaction between the tidal currents and waves modifies their mutual characteristics. Wave propagation changed depending upon the tidal activity. During the ebb tide supplementary wave refraction occurred. Tidal currents flowing against the direction of the wave propagation causes a decrease in its velocity and wavelength (Dean and Dalrymple, 1984). In this way,
the morphology of the wave fronts was modified by the ebb current and, as a consequence, also their direction of propagation. Tidal currents, that were channelized along the west margin due to the jet effect, caused the wave fronts to be concentrated by the opposing jet flow and to deform, and to break eastwards creating the famous “Mundaka left wave”.

In general, the tidal currents may also be modified by wave action. Waves make the exit of the ebb tide water difficult (Grant and Madsen, 1979). In the Oka estuary, waves approach mainly from the northwest and force the ebb current to move to the western margin where the wave heights are smaller. This process, together with the sand transport towards the inlet on the northern beach area, is responsible for the westward displacement of the new “anomalous” inlet to its former position, contributing in this way to the restoration of the normal conditions in the estuary mouth.

The morphodynamical evolution of the Mundaka sand bar during the study period documents its natural restoration, departing from an initial situation (May 2005) when it was fragmented, sand starved, and not orientated favourably for the formation and development of the characteristic “Mundaka left wave”. The additional sand supply during the summer caused the rapid reconstruction of the sand bar, both horizontally and vertically. By the end of the summer its conditions were adequate for the formation of the famous surfing wave, although its break point moved slightly southward and it did not extend as far eastwards as before. During the winter, the eastern margin of the sand bar acquired a more oblique orientation to the wave approach, giving place to a more progressive wave break, and increasing in this way the length of the “surfable” line. However, the presence of the anomalous inlet across the sand bar during December 2005-February 2006 altered the breaking features of the smaller waves. Since March 2006 the inlet channel has relocated itself at the western margin of the estuary, allowing the sand bar to recover its previous morphology and magnitude and was able to generate that peculiar “left wave”.

The graph shows the monthly sedimentary budget (accumulation/erosion) between May 2005 and April 2006 on the Mundaka sand bar area. The sediment budget is represented in different color intensities, with red indicating erosion and green indicating accumulation. The key for these colors is provided in the lower part of the graph.
Fig. 14.- Sedimentary budget (accumulation/erosion) of a north-south profile in the central area of the outer estuary for the summer (July 2005) and winter (February 2006) periods.

Fig. 14.- Balance sedimentario (deposición/erosión) de un perfil norte-sur en el área central de la zona exterior del estuario para los periodos estival (Julio 2005) e invernal (Febrero 2006).
In summary, the general process was sediment transport from the northeast to the southwest along the rocky eastern margin of the open bay and the northern area of Laida beach towards the estuary inlet. Whence, some sediment was introduced into the estuary to feed the flood delta, and the remainder of the sediment was transported seawards to restore the Mundaka sand bar (ebb delta). This process operated throughout the whole year although seasonally, according to the dominance of the main responsible process: tidal flows during the summer and wave action during the winter (Fig. 15).

The changes of the different parameters that control this situation are the cause of the natural morphodynamical variability of the outer estuary. This area is always constituted by the same elements (beach, inlet, ebb delta, flood delta), but in detail they exhibit great variability at different scales, from daily to yearly, although maintaining a dynamic equilibrium (except when interfered by anthropogenic influences).

4. Conclusions

The sedimentary equilibrium of the Oka estuary mouth is controlled by the continuous movement of sand between its different morphological elements. There is a dynamic equilibrium due to the variable intensity with time of the various processes.

Since the last dumping of sand, the volume of eroded sediment on the landward of Laida beach increased substantially, reaching a value of 11,000 m³/month in the second half of 2003. This increase of the rate of erosion in such a short period of time introduced an enormous amount of sand into the inlet area. A part of this sand was deposited there, caused the cutting of a new anomalous inlet to the east and modifying the ebb delta. Later, the erosion rate decreased and almost matched the normal values before the sand dumping.

During the summer, on the intertidal area north of Laida beach sand ridges migrate to the southwest transp-
ing sediment from the northeastern area of the open bay towards the beach and inlet. In this way, a typical summer beach profile characterized by ridges and runnels was produced in the lower intertidal area (low-tide terrace) and a wide berm was generated. The “anomalous” inlet, generated as a consequence of the infilling of the original inlet, disappeared in July-August 2005 due to the displacement of the sand bars discussed above and the transport of water and sediment induced by the ebb tide. These processes strengthened the development of the Mundaka sand bar and returned the inlet to its normal position close to the western rocky margin of the estuary.

During winter, the sand ridges present on the low-tide terrace in summer disappeared and part of the sediment was introduced into the estuary and the remainder was transported to the proximal area of the Mundaka sand bar, to leave a flat rippled intertidal area. Furthermore, the slopes between the subtidal and intertidal areas and the intertidal and supratidal areas (berm) were more pronounced giving place to a typical winter profile.

Generally, the annual process showed a sediment transport from the northeast to the southwest along the east rocky margin of the open bay and the northern area of Laida beach to the estuarine inlet. From there, some sediment was moved landwards into the estuary to feed the flood delta and some to seawards to feed the Mundaka sand bar (ebb delta). This process operates throughout the whole year but whereas tidal dynamics are more important during summer, incident wave dynamics are dominant during winter.

In summary, the extra sand introduced into the lowestestuarine system caused an upset in the natural processes, and these were finally accommodated by the system which after 3 years restored the situation to what it was before the dumping. No anthropogenic corrective measurements were adopted on the outer estuary during the study period and the environment recovered naturally with the establishment of the normal morphological features. It is hoped that this natural restoration will be more stable, long-lasting and reliable in order to ensure the future of the “Mundaka left wave”.

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References


