



**From source rocks to fluvial sediments:
Ecological and environmental significance of planktonic Foraminifera
in the Guadalquivir River-Estuary (SW Spain)**

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Abstract: This study examines the texture and reworked planktonic Foraminifera present in dredged and non-dredged sediments from the Guadalquivir Estuary (SW Spain). Dredging significantly changes the grain size of natural silty-clay sediments to fine silty sands in dredged areas. The density and diversity of planktonic Foraminifera, which originate from Cretaceous and Neogene formations, as well as tidal cycles, decrease slightly with dredging. Possible applications of similar studies in Geology and environmental analysis are included.

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- grain size;
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Résumé : *Des roches d'origine aux sédiments fluviaux : Importance écologique et environnementale des foraminifères planctoniques dans l'estuaire du fleuve Guadalquivir (sud-ouest de l'Espagne).*- Cette étude examine la texture et les foraminifères planctoniques remaniés présents dans des sédiments dragués ou non dragués de l'estuaire du Guadalquivir (sud-ouest de l'Espagne). Le dragage modifie significativement la granulométrie des sédiments naturels limono-argileux, qui deviennent des sables fins limoneux dans les zones draguées. Sous l'effet du dragage, la densité et la diversité des foraminifères planctoniques, issus de formations du Crétacé et du Néogène, ainsi que des cycles tidaux, diminuent légèrement. Les applications potentielles d'études similaires en géologie et en analyse environnementale sont également présentées.

Mots-clefs :

- granulométrie ;
- foraminifères planctoniques ;
- dragage ;
- sédiments estuariens ;
- applications

1. Introduction

A drainage basin comprises the area that collects surface-runoff water and surface springs from aquifers and transports them, together with eroded sediments and anthropogenic inputs (industry, agriculture, etc.), to tributaries and ultimately to the main channel of a river. Consequently, the main watercourses are the final recipients of hydrological, environmental and geological vicissitudes, such as periods of drought or flooding, sediment avalanches, pollution from various sources or invasion of exotic species, among others (GARCÍA-ALONSO *et al.*, 2015; SÁEZ-GÓMEZ & PRENDA, 2019; IZQUIERDO *et al.*, 2024; MALEDE *et al.*, 2025). The species that populate its subtidal floors, waters and the adjacent floodplain are distributed according to various environmental parameters, such as bottom substrate, hydrological connectivity, conductivity, pH, Eh, nutrient content, pollution indices or the presence of prey and predators (HILKER & LEWIS, 2009; CARBONEL *et al.*, 2011; SILVA & HUAMANTINCO, 2022; POI *et al.*, 2025).

When the sediments of some rivers are sampled, these living organisms and their past generations are intermingled with the remains of fossil groups from the erosion of the geological materials that make up their drainage basin (SPENCER & ROGERS, 1970; EATON *et al.*, 1989; PINKSEER *et al.*, 2011). The latter may originate from earlier geological periods and their palaeoecology will depend on the depositional environment of the geological units that contained them. These reworked fossils may include planktonic Foraminifera, a group of microscopic protists characteristic of marine environments that are very useful in paleoceanographic reconstructions, paleoclimatic changes or biostratigraphic applications

(SIJINKUMAR *et al.*, 2012; GRADSTEIN *et al.*, 2021; MARTINELLI *et al.*, 2025). Knowledge of its biostratigraphic distribution, together with the micropaleontological analysis of the rocks that make up the drainage basin of a river, allows the determination of its origin and tracing the route followed to the main riverbed.

This paper analyses the planktonic Foraminifera present in the current sediments of the Guadalquivir River between its mouth and the city of Seville (SW Spain) (Fig. 1). The main objective is to determine their origin based on the biostratigraphy of the species identified and the microfossil content of the geological formations in its drainage basin, as well as their possible geological applications.

2. The Guadalquivir River-Estuary

The Guadalquivir River is the main fluvial stream in southern Spain, with a length of 657 km. This river forms a wide estuary, stretching from the city of Seville in the north to its mouth on the Atlantic Ocean in the town of Sanlúcar de Barrameda (Fig. 1.A). In this sector, its width varies between 200 and 800 m and the average depth of the channel is 7 m, although it is highly variable and may increase locally due to periodic dredging to facilitate the passage of ships to the port of Seville.

The water regime of the Guadalquivir River is seasonal in nature, with very marked low water levels and flooding during autumn and winter. Its flow is also highly variable, with an annual average of 185 m³ and maximums exceeding 1000 m³ during rainy periods (VANNEY, 1970; BAENA *et al.*, 2006). The tidal regime is mesomareal and semidiurnal, with an average tidal range of 3.6 m (BORREGO *et al.*, 1993). In its

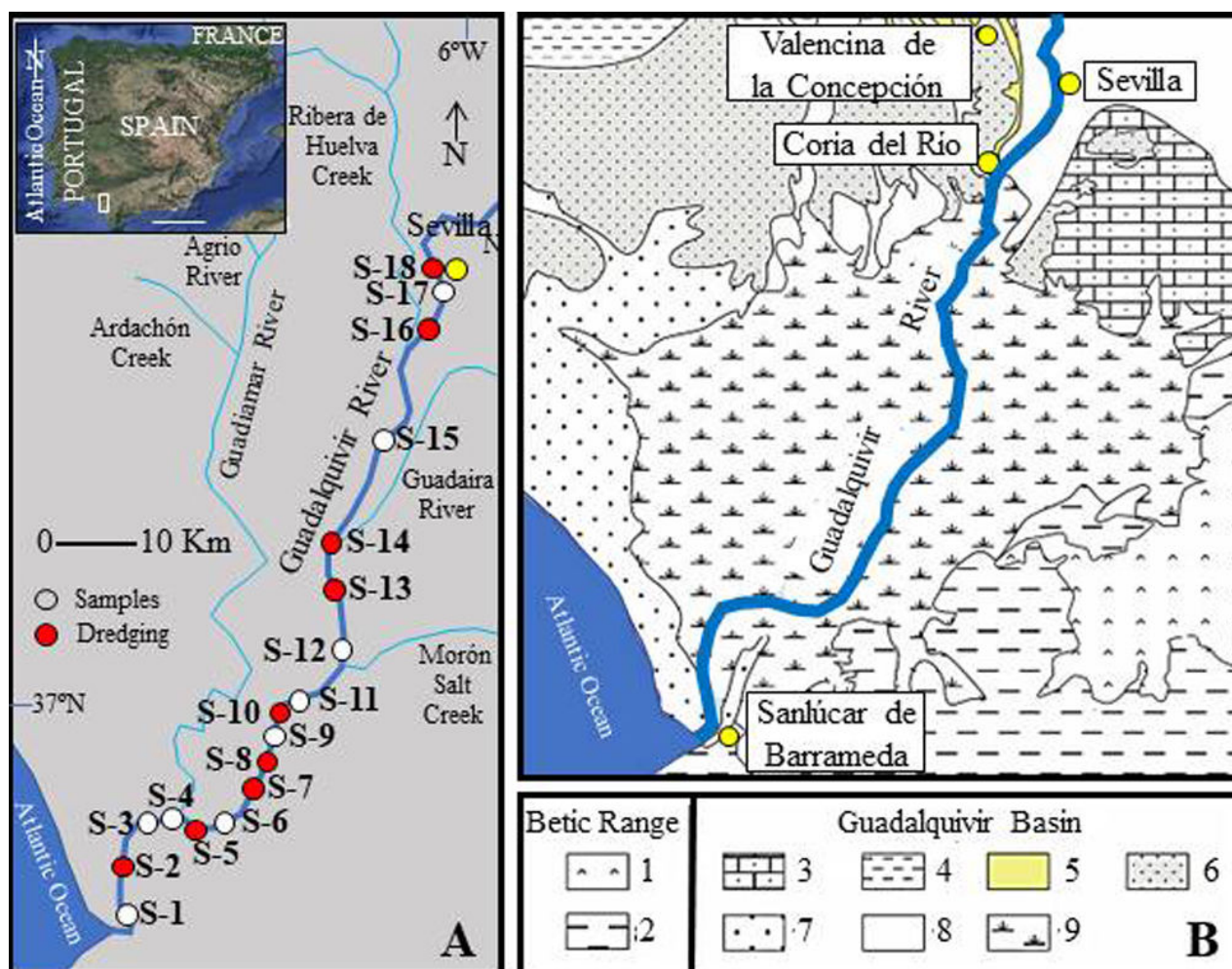


Figure 1: A) Location of the Guadalquivir River-Estuary and the samples analysed (red circles: samples extracted in dredging areas); B) Geological map of the Guadalquivir River-Estuary and adjacent zones (modified from CÁCERES *et al.*, 2024); Betic Range. 1: Triassic clay and gypsum; 2: Miocene marl, sandstone, and flint Stone. Guadalquivir Basin. 3: Tortonian sandstone and conglomerate; 4: Miocene marl, Blue Marl Unit; 5: Transition Facies; 6: Pliocene sand and silt; 7: Quaternary sand (dunes and beaches); 8: Quaternary fluvial deposits (conglomerate, sand, and clay); and 9: Salt marshes.

estuary, the hydrodynamic regime is controlled by the tides, the great width of the river channel and a slight slope. Other anthropogenic factors include the construction of the Alcalá del Río reservoir, located about 15 km upstream from the city of Sevilla. The water temperature remains between 10 and 28°C, and there is no vertical stratification. However, there is a horizontal salinity gradient from the mouth (17‰-27‰) to 30 km upstream, where it does not usually exceed 4‰. However, during periods of heavy rainfall, the river's flow is so voluminous that the marine influence almost disappears (BALDO *et al.*, 2001). Turbidity is low at the mouth of the Guadalquivir River and increases significantly between this point and the city of Sevilla, making this river one of the most turbid in the Iberian Peninsula (AMEZTOY *et al.*, 2009).

The depositional regime is controlled by floods and the morphology of the riverbed, tides and anthropogenic action, the latter being decisive, due to the significant modifications made, such as reservoirs, port works, locks, canals and dredging, which have altered the natural regime of the

river. In the northern sector of the estuary, the flow regime is characterised by alternating areas with predominantly depositional processes and areas with predominantly transport processes. In this area, continuous dredging operations have removed much of the deposited sediment and altered the natural depositional regime of the river, whose tendency to deposit is distorted by an apparent state of equilibrium caused by dredging. The southern sector is characterised by a variable regime, with sections dominated by erosive processes and other sections dominated by transport processes (COSTA *et al.*, 2009).

On the other hand, the course of the Guadaira River, the most important tributary on the eastern bank of the estuary, has been diverted and channelled to prevent flooding in the city of Sevilla. The channelling works have caused the floodplain to be filled with between 2 and 3 metres of sediment, with a total volume of 6,900.000 m³ (LLUCH *et al.*, 2025), which acts as a partial reservoir for the upstream sediments eroded by this river.

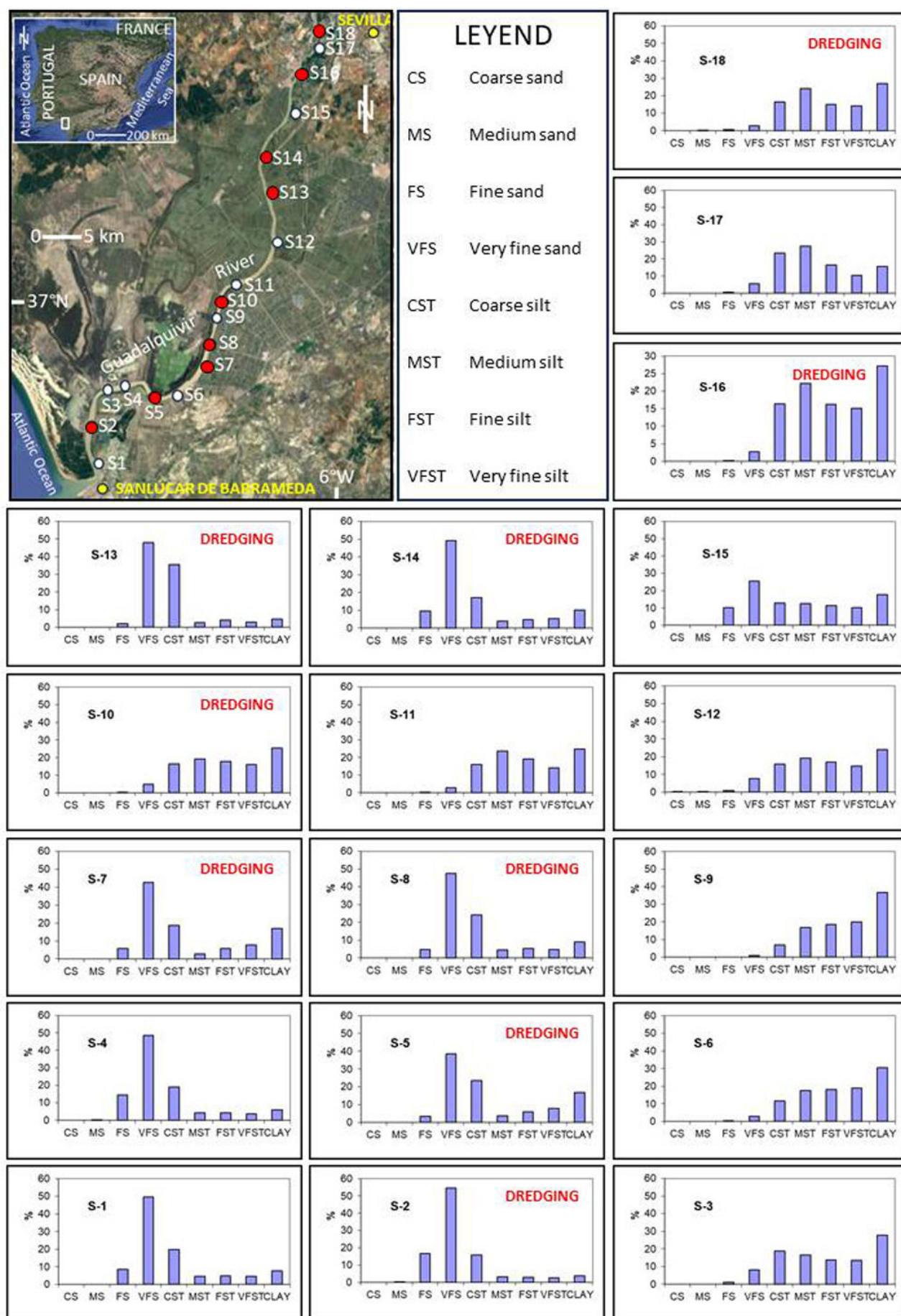


Figure 2: Histograms of grain size distribution.



3. Material and methods

Material

The sampling area extends from the lock at the port of Seville to the mouth of the Guadalquivir River. Sampling was carried out using a 4.5 m- long vessel belonging to the company Navios de Aviso SLU. Eighteen surficial sediment samples (Fig. 1.A: S-1 to S-18) were obtained using a Van Veen dredge from the bottom of the submerged channel, the position of which was determined using a Garmin ETREX GPS device with metric precision. The samples were stored in labelled self-sealing plastic bags until further analysis, kept at 4°C until arrival at the laboratory, where they were dried in an oven at 60°C.

Methods

Grain size distribution was determined using a Malvern Mastersizer 2000 laser particle analyser (Malvern Instruments Ltd, UK) at the University of Huelva. Each sample was measured in triplicate for 30 seconds, with 10-second breaks between measurements, using a darkening range of 10–20% and a stirring speed of 1500–2000 rpm (JOHANNESSON & ZHOU, 1999).

Eighteen subsamples (40 g) were separated for the study of planktonic Foraminifera sieved through a 63 µm- diameter mesh sieve. The taxo-

nomic determination of the species present and their biostratigraphic range was carried out in accordance with WAVE *et al.* (2011), BOUDAGHER-FADEL (2013) and two databases (Mikrotax and the World Register of Marine Species –WoRMS-).

4. Results

Textural analysis

The riverbed near the city of Seville has a bottom composed of clayey silt. The granulometry is dominated by clays (range: 10–25%) in the dredged sectors and by medium silts (20–25%) and coarse silts (15–20%) in the undredged areas (Fig. 2). The average of sand does not exceed 10% in this area.

The rest of the channel shows a notable dichotomy between dredged and undredged areas. The granulometric distribution of the former is clearly leptokurtic (except for S-10), with moderately well sorted sediments composed of very fine sands (up to 55%) and, to a lesser extent, coarse silts (up to 30%). In contrast, undredged areas have much finer sediments, with platykurtic distributions characterised by silty sediments with significant percentages of clay (12–30%). In these undredged areas, samples S-1 and S-4, close to the mouth of the Guadalquivir River, should be distinguished, with histograms very similar to those of the dredged areas.

Table 1: Distribution of planktonic foraminiferal taxa obtained from the bottom sediments of the Guadalquivir River. Red: dredged areas.

Species/Samples	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17	S-18
<i>Beella praedigitata</i> (PARKER, 1967)	1			1		1		5										
<i>Globigerina bulloides</i> ORBIGNY, 1826	7	10	7	2	2	2		1	4			2	4	2		2	4	
<i>Globigerina eamesi</i> BLOW, 1959					1	1					1					2	1	
<i>Globigerina tetracamerata</i> BOLLI & BERMÚDEZ, 1965	1							4										
<i>Globigerinoides conglobatus</i> (BRADY, 1879)							1					2		2				
<i>Globigerinoides extremus</i> BOLLI & BERMÚDEZ, 1965				1														
<i>Globigerinoides obliquus</i> BOLLI, 1957	3		5		2	2	1					2	1				2	
<i>Globigerinoides ruber</i> (ORBIGNY, 1839)			2	1	3	2		6	1	2			1	2			3	
<i>Globoconella inflata</i> (ORBIGNY, 1839)	3	3		1	2	1		1	4					4			3	
<i>Globorotalia (Truncorotalia) crassaformis</i> (GALLOWAY & WISSLER, 1927)	6		2			2			1				1					
<i>Globorotalia menardii</i> (ORBIGNY in PARKER <i>et al.</i> , 1865)	2	1	1	1	4	1	1					3	1			1	1	
<i>Globorotalia truncatuloides</i> (ORBIGNY, 1839)														1				
<i>Globotruncana</i> spp. [<i>Globotruncana mariei</i> BANNER & BLOW, 1960 + <i>Globotruncana arca</i> (CUSHMAN, 1926)]						3	10			4	10	2	3	2				
<i>Globoturborotalita nepenthes</i> (TODD, 1957)												1	1					
<i>Neogloboquadrina acostaensis</i> (BLOW, 1959)	1																	
<i>Neogloboquadrina humerosa</i> (TAKAYANAGI & SAITO, 1962)	2	1	2		1	1		4	3		3	4				2	3	
<i>Orbulina suturalis</i> BRÖNNIMAN, 1951					1													
<i>Orbulina universa</i> ORBIGNY, 1839	8	5	4	4	3	2	4	8	3			3	7			3	2	
<i>Sphaeroidinella dehiscens</i> (PARKER & JONES, 1865)				2							1							
<i>Sphaeroidinellopsis seminulina</i> (SCHWAGER, 1866)	2			1			1	1					1				1	
<i>Trilobatus trilobus</i> (REUSS, 1850)	2	4	3				1											
<i>Turborotalita quinqueloba</i> (NATLAND, 1938)									1							1		
Number of species	12	6	8	9	9	10	6	8	7	1	2	8	8	5		6	9	
Individuals/40 grams	38	24	26	14	19	18	19	30	17	6	14	20	20	13		11	20	



Planktonic Foraminifera

Planktonic Foraminifera are scarce in the sediments at the bottom of the Guadalquivir River, and only 309 specimens belonging to 23 species have been extracted (Table 1). None of the 18 samples studied exceeded 40 individuals per 40 grams, although the sample closest to the mouth of the Guadalquivir River came close to this amount (Fig. 1.A: sample S-1). This abundance is slightly higher on average in the undredged samples (0–38 individuals/40 g of bulk sediment; M-mean: ~19 individuals/40 g) than in the dredged samples (0–30 individuals/40 g; M: ~16 individuals/40 g). On the other hand, the number of species per sample ranges from 0 to 12, varying from maximum diversity in sample S-1 to the disappearance of these microorganisms in two samples located near the city of Seville (S-15 and S-18). This diversity is again slightly higher on average in the undredged samples (0–12 species/sample; M: ~7 species/sample) than in the dredged samples (0–9 species/sample; M: ~6 species/sample).

The most abundant species are *Orbulina universa* ORBIGNY, 1839 (Fig. 3.e; 56 individuals) and *Globigerina bulloides* ORBIGNY, 1826 (Fig. 3.c; 49 individuals) and, to a lesser extent, *Neogloboquadrina humerosa* (TAKAYANAGI & SAITO, 1962) (26 individuals), *Globigerinoides ruber* (ORBIGNY, 1839) (Fig. 3.h; 23 individuals), *Globoconella inflata* (ORBIGNY, 1839) (22 individuals), *Globigerinoides obliquus* BOLLI, 1957 (18 individuals) and *Globorotalia menardii* (ORBIGNY in PARKER, JONES & BRADY, 1865) (Fig. 4.c-d; 17 individuals).

These seven species account for more than 68% of the individuals extracted and are distributed throughout the Guadalquivir River-Estuary. Others, such as *Globotruncana mariei* BANNER & BLOW, 1960 (Fig. 5.a-c) and *Globotruncana arca* (CUSHMAN, 1926) (Fig. 5.d-f), appear downstream from the mouth of the Guadaira River and disappear near the mouth of the Guadalquivir River.

No evidence of corrosion has been observed in this group, which is generally in good condition in most specimens. Three main types of taphonomic processes can be distinguished: i) wear on wall ornamentation; ii) small impact depressions probably caused by the transport of individuals; and iii) recrystallisation in some Cretaceous specimens (e.g., Fig. 4.b-c, .f). These processes mainly affect larger individuals of *Globigerinoides ruber*, *Globorotalia menardii*, the two species of *Globotruncana*, *Neogloboquadrina humerosa* (Fig. 4.b), *Orbulina universa* and *Trilobatus trilobus* (REUSS, 1850).

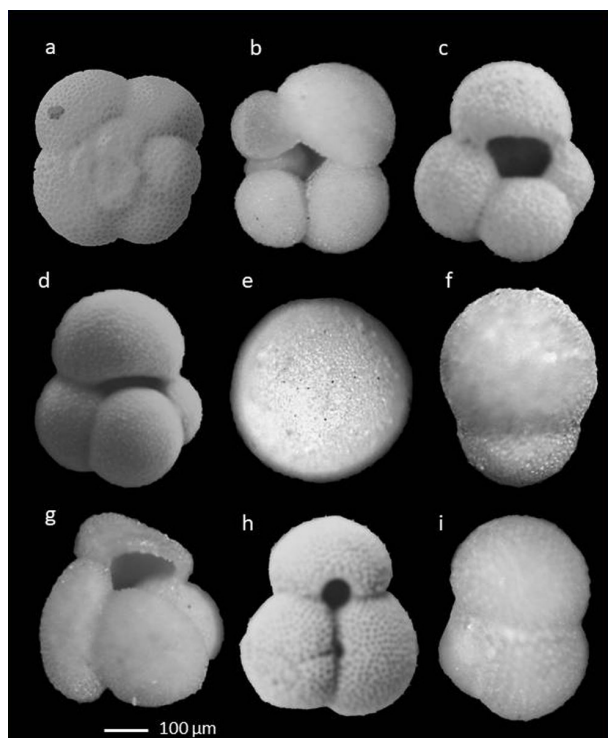


Figure 3: a-b) *Neogloboquadrina acostaensis* - sample S-1; c) *Globigerina bulloides* - sample S-17; d) *Globigerina eamesi*- sample S-6; e) *Orbulina universa* - sample S-8; f) *Orbulina suturalis* - sample S-5; g) *Globigerinoides extremus*- sample S-4; h) *Globigerinoides ruber* - sample S-8; i) *Trilobatus trilobus*- sample S-3.

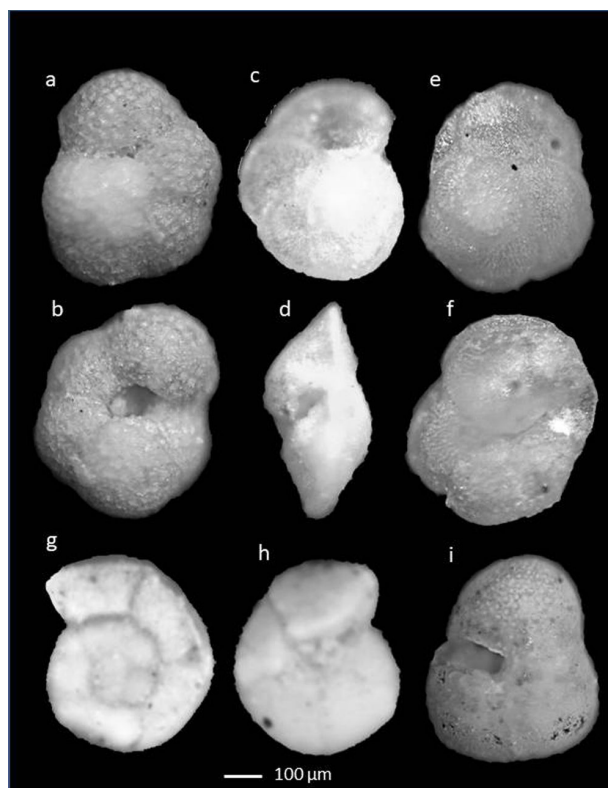


Figure 4: a-b) *Neogloboquadrina humerosa* - sample S-12; c-d) *Globorotalia menardii* - sample S-5; e-f) *Globorotalia crassaformis* - sample S-1; g-h) *Globorotalia truncatulinoides* - sample S-14; i) *Sphaeroidinella dehis-cens* - sample S-4.

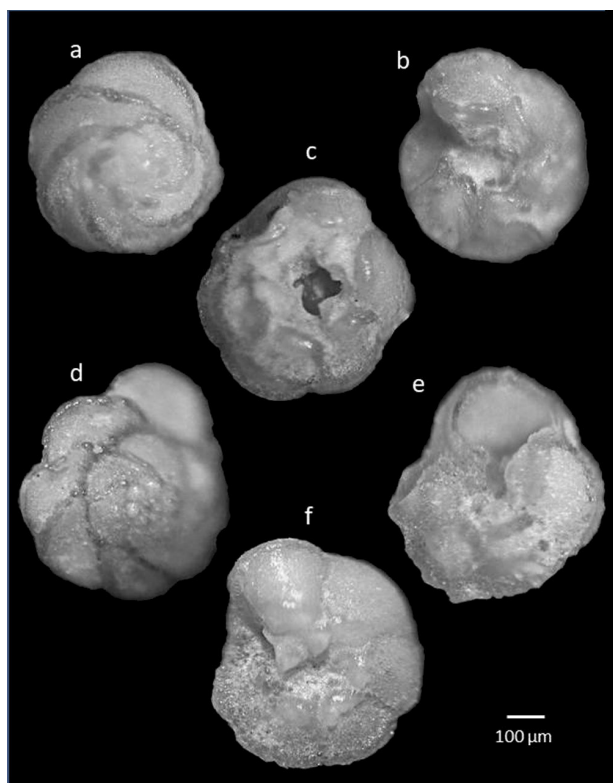


Figure 5: a-c) *Globotruncana mariei* - sample S-7; d-f) *Globotruncana arca* - sample S-11.

5. Discussion

Texture vs planktonic Foraminifera

The dredging of river channels has a significant impact on their hydrodynamics, sedimentation processes and biota, as it involves changes in their depth, current velocity and even erosion rates of their banks (YAO *et al.*, 2023; DONÁZAR-ARAMENDIA *et al.*, 2024). This anthropogenic activity generally causes the affected river sections to shift from a predominance of silt-clay fractions to a very significant increase in sand- grain sizes, because dredging removes finer sediments (NAYAR *et al.*, 2007; LIU *et al.*, 2024). This general pattern is consistent with the textural distribution of the dredged and undredged areas of the Guadalquivir River, but it is not confirmed in some special samples: i) S-10, a silty-clayey sample located in a dredged but high-energy area (COSTA *et al.*, 2009), and ii) S-1 and S-4, two sandy samples in undredged areas but with a high bioclastic content introduced by the tides near the mouth of the Guadalquivir River (GONZÁLEZ-REGALADO *et al.*, 2019).

The presence of fine sediments in both dredged and undredged areas near the city of Seville (Fig. 1: samples S-18 to S-16) can be explained by the regulatory action of the city's port lock. This area is channelled and separated from the natural course of the river, so it is only affected by weak tidal currents and the dominant depositional process is the settling of fine suspended material (COSTA *et al.*, 2009). This peculiar arrangement could explain the absence of planktonic

Foraminifera near the aforementioned lock (S-18), while tidal inflows would justify their presence in the vicinity of the river's natural course (S-16 and S-17). Consequently, multidisciplinary geological studies of dredged rivers must take into account the presence of sectors with differentiated hydrodynamics.

In the rest of the riverbed, the differences in the density and diversity of reworked planktonic Foraminifera between dredged and undredged areas can be partially explained by the impact of dredging, which would contribute to the breaking of the thin shells of these microorganisms. In addition, Foraminifera tend to disappear in dredged areas of current estuaries, because dredging disturbs the natural depositional processes (KAPPENBERG & GRABEMAN, 2001). On the other hand, estuarine zones with high sand contents are unfavourable for the development and deposition of Foraminifera at present (MOJTAHID *et al.*, 2016; FRANCESCANGELI *et al.*, 2018).

Biostratigraphic range:

The origin of reworked species

The identified species can be divided into three groups, depending on their biostratigraphic range (Table 2).

i) Late Cretaceous species (*Globotruncana arca*, *Globotruncana mariei*). These species have been identified in Cretaceous materials belonging to the Betic System (Subbetic zone) in southern Iberian Peninsula (IGME, 1979; ARZ & MOLINA, 2001; GILABERT *et al.*, 2021) and consequently, would originate from the Mesozoic formations located on the eastern bank of the Guadalquivir River, eroded by some of its tributaries (Fig. 1.A: Guadaira River, Morón Salt Creek). *Globotruncana arca* has been identified in Upper Campanian biomicrites located in the basin of this river (IGME, 1977).

ii) Ten extinct species, with a wide biostratigraphic range spanning more than 7 million years with LADs from the Pliocene to the Pleistocene. They are common in the Miocene-Pliocene clayey and sandy formations of the western sector of the Guadalquivir Basin near the western bank of the Guadalquivir River (SIERRO, 1982, 1987; PÉREZ-ASENSIO *et al.*, 2018);

iii) Eleven extant species, most of them cited in the Neogene and Quaternary sediments of the southwestern Guadalquivir Basin and with FADs ranging from the Palaeogene to the Pleistocene (WAVE *et al.*, 2011; BOUDAGHER-FADEL, 2013). Some species, such as *Globorotalia menardii* or *Turborotalita quinqueloba* (NATLAND, 1938), have also been found in other Neogene basins in southern Spain (AGUIRRE *et al.*, 2022). These species are distributed throughout the Guadalquivir River-Estuary (Table 1) and most likely originate from the aforementioned Neogene-Quaternary sediments, although the increase of these species near the mouth does not rule out their introduction by the tides because

**Table 2:** Biostratigraphic range of the planktonic species (extracted from WAVE *et al.*, 2011; BOUDAGHER-FADEL, 2013; Mikrotax and WoRMS). FAD: first appearance datum; LAD: last appearance datum.

Species	FAD (Myr)	LAD (Myr)
<i>Beella praedigitata</i> (PARKER, 1967)	8.58-6.6	Extant
<i>Globigerina bulloides</i> ORBIGNY, 1826	28.1-26.9	Extant
<i>Globigerina eamesi</i> BLOW, 1959	Late Miocene	
<i>Globigerina tetracamerata</i> BOLLI & BERMÚDEZ, 1965	Lower Miocene to Upper Miocene	
<i>Globigerinoides conglobatus</i> (BRADY, 1879)	22.4-21.1	1.3
<i>Globigerinoides extremus</i> BOLLI & BERMÚDEZ, 1965	8.9	2
<i>Globigerinoides obliquus</i> BOLLI, 1957	22.4-21.1	1.3
<i>Globigerinoides ruber</i> (ORBIGNY, 1839)	11.6-10.2	Extant
<i>Globoconella inflata</i> (ORBIGNY, 1839)	3.1-2.4	Extant
<i>Globorotalia (Truncorotalia) crassaformis</i> (GALLOWAY & WISSLER, 1927)	4.3	Extant
<i>Globorotalia menardii</i> (ORBIGNY in PARKER <i>et al.</i> , 1865)	13.4-11.8	Extant
<i>Globorotalia truncatulinoides</i> (ORBIGNY, 1839)	1.9	Extant
<i>Globotruncana arca</i> (CUSHMAN, 1926)	85.6-83.6	69.3-67.6
<i>Globotruncana mariei</i> BANNER & BLOW, 1960	83.6-79.3	73.8-71.7
<i>Globoturborotalita nepenthes</i> (TODD, 1957)	11.6	4.4
<i>Neogloboquadrina acostaensis</i> (BLOW, 1959)	9.8	1.9-0.6
<i>Neogloboquadrina humerosa</i> (TAKAYANAGI & SAITO, 1962)	8.6	1.88-0.61
<i>Orbulina suturalis</i> BRÖNNIMAN, 1951	15.1	3.1-1.9
<i>Orbulina universa</i> ORBIGNY, 1839	14.5	Extant
<i>Sphaeroidinella dehiscens</i> (PARKER & JONES, 1865)	5.6	Extant
<i>Sphaeroidinellopsis seminulina</i> (SCHWAGER, 1866)	17.5	3.2
<i>Trilobatus trilobus</i> (REUSS, 1850)	23-22.4	Extant
<i>Turborotalita quinqueloba</i> (NATLAND, 1938)	38-35.9	Extant

others, such as *Globigerina bulloides*, *Globoconella inflata*, *Globorotalia truncatulinoides* or *Globigerinoides ruber*, are also frequent in the north-eastern Atlantic and adjacent areas of the Mediterranean sea (SALGUEIRO *et al.*, 2008; PALACKS *et al.*, 2021). In this area, specimens of these species are generally well preserved, whereas those found farther inland in the estuary show surface depressions and erosion. The former are likely to be the results of current tidal action, as in Cretaceous-Paleogene lagoonal and coastal lake paleoenvironments northeast of the Iberian Peninsula (DÍEZ-CANSECO *et al.*, 2014), while the latter are more likely to have originated from the adjacent Neogene formations.

The comparison between the distribution and taphonomy of planktonic Foraminifera in source rocks and fluvial sediments allows us to make some additional considerations to those previously indicated. The Neogene species identified in the fluvial sediments are very abundant and well preserved in the Messinian marls and silts of the Gibralferrón Clay Formation (CIVIS *et al.*, 1987), which forms the base of the stratigraphic column in the western sector of the province of Seville crossed by the Guadalquivir River and the streams that flow into the Doñana National Park or directly into the Guadalquivir River. These marine species are also common, although in poorer condition, in the yellowish Pliocene silts overlying this formation in quarries and surface sections near these watercourses (SIERRO, 1987; DÍAZ *et al.*, 1987). Consequently, this formation is considered to be the most likely source of the Neogene planktonic Foraminifera identified in the Guadalquivir riverbed.

Planktonic Foraminifera as sedimentary tracers

Given the intensive dredging of the Guadalquivir River, it is difficult to obtain reliable data on how planktonic Foraminifera might be captured, stored and remobilised in different sub-environments of the estuary, or how these processes interact with its hydrodynamics. However, some assumptions can be made based on their size and distribution:

i) In the sediments of the Guadalquivir River, Neogene planktonic Foraminifera generally range in size from 300 µm to 500 µm (Figs. 2 - 3). However, these microorganisms are grouped in the 100-177 µm fraction in Neogene sediments located west of the city of Seville, which would indicate that there is selective destruction of smaller specimens from the source rock to the estuarine sediments (DÍAZ *et al.*, 1988).

ii) The Cretaceous specimens are larger than the Neogene ones on average and are concentrated near the mouth of the tributaries on the eastern bank of the Guadalquivir, which drain Mesozoic formations. In general, Foraminifera transported in suspension in estuaries are very small-sized (< 200 µm; WANG & MURRAY, 1983) and this distribution of Cretaceous species would indicate limited transport as bed-load once they are carried into the main channel.





Applications in geology and environmental analysis

In estuaries, planktonic Foraminifera act as sedimentary particles that can be transported from geological formations that comprise river drainage basins, as well as being introduced during tidal cycles. Based on these possible origins, various applications can be considered:

i) Assessment of the tidal influence area, in conjunction with measurements of physical-chemical parameters such as salinity or the chemical composition of the waters. As pointed out by WANG and MURRAY (1983), the abundance of exotic tests shows a progressive increase with increased tidal strength. In the case of the Guadalquivir River, this influence reaches the city of Seville, according to previous studies of its tidal dynamics (e.g., ÁLVAREZ *et al.*, 2001) and the aforementioned distribution of planktonic Foraminifera.

ii) Determination of the source area from which they originate, in connection with additional microfaunal studies of these geological units. This possible application has already been used to explain the presence of reworked benthic Foraminifera in estuarine and shelf environments in India (NIGAM & SETTI, 1980; NIGAM *et al.*, 2005).

iii) Delimitation of ancient drainage networks, in coordination with the study of river terraces. For example, the presence of reworked planktonic Foraminifera has made it possible to infer an ancient fluvial system during the Rupelian in the Upper Rhine Graben (PIRKEENSEER *et al.*, 2009).

However, care should be taken when applying it directly if:

i) Planktonic Foraminifera appear in both the geological formations of river basins and the current ocean masses adjacent to the studied rivers, making taphonomic analysis a basic tool for differentiating the origin of these specimens;

ii) There is evidence of taphonomic bias derived from the size of planktonic Foraminifera or their shape (e.g., globular versus keeled); or

iii) Anthropogenic interventions (e.g., dredging, dams, etc.) affect the transport and resilience of these microorganisms in these environments.

6. Conclusions

Textural and microfaunal analysis of dredged and undredged areas of the Guadalquivir River-Estuary (south-western Spain) has revealed the effect of dredging on sediments and the reworked planktonic Foraminifera present in them. This anthropogenic action significantly increases grain size and slightly reduces the average number of species and individuals per gram, except in areas with high energy or with significant percentages of marine bioclasts introduced by the tides. The biostratigraphic range of planktonic Foraminifera species allows three source areas to be established: Cretaceous materials from the Betic Range, Neogene formations from the Guadalquivir

Basin, and tidal contributions. The distribution of Cretaceous species is associated with the mouths of tributaries on the eastern bank, while Neogene species originate from tributaries on the western bank. Consequently, it is possible to apply the results to the delimitation of ancient river basins, the determination of the geological formations from which these microorganisms originate, or the extent of tidal cycles in estuaries.

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