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Foraminiferal distribution in two estuarine intertidal mudflats of the French Atlantic coast: testing the Marine Influence Index

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Abstract: This study focuses on the foraminiferal distribution on intertidal mudflats of two contrasted estuaries (Auray and Vie) along the French Atlantic coast. In both estuaries the foraminiferal communities are dominated by *Haynesina germanica* and the *Ammonia tepida* group. Stations located near the outlets show a high diversity and abundance of species of the genus *Elphidium*. Stations in the inner estuary show a higher proportion of agglutinated species (*Ammotium salsum*, *Ammobaculites agglutinans*). Multivariate statistical analysis suggests that the distance to the sea, and the percentage of fine sediment (< 63µm) are the two main parameters explaining the foraminiferal distribution. Chemical analyses of the sediment show that the two studied estuaries are not affected by major anthropogenic pollution, so that the faunas should mainly reflect the natural controlling parameters. Three indices of environmental quality commonly used in coastal areas show counter-intuitive differences between stations, suggesting that these indices may be less reliable for intertidal estuarine mudflats. The newly developed Marine Influence Index (MII) integrates three major ecological factors: the position of the sampling point on the salinity gradient, the emergence time at low tide and the relative importance of fresh water discharge. In our dataset, MII shows significant correlations with the controlling environmental parameters (distance to the sea, percentage grains< 63µm), as well as with the foraminiferal patterns (PCA axis 1, species richness, percentage of *Elphidium* spp. and *Quinqueloculina* spp.). These results suggest that the MII explains a substantial part of the faunal variability on estuarine intertidal mudflats, and can be used to detect deviations from the natural distribution patterns in response to anthropogenic pollution.

Keywords: Estuary; biomonitoring; foraminifera; environmental parameters

Supplementary material

Table S1. Overall characterisation of the Auray and Vie estuaries.

	Auray	**Vie**
Estuary type	Ria	Lowland estuary
Limit of tidal influence and saltwater intrusion	19.8 km	8 km (estimated 16.8 km before the construction of a dam at 8 km from the mouth)
Width at the mouth	950m	200m
Catchment area	324km²	84km²
Average water flow per year (last 49 years) (Banque HYDRO)	4.53 $m^3.s^{-1}$	1.17 $m^3.s^{-1}$
Average yearly rainfall	951mm	901mm
Overall Ecological status (2019 MFD)	Average	Good

Table S2. Description of the sampling stations in Auray and Vie estuaries.

Auray estuary			
Site n°	**Station n°**	**Altitude**	Localisation within the estuary
Site 1	Station 1A: Upper mudflat, near the slipway	2.52m	Outer estuary
	Station 1B : Center of the mudflat, near the slipway	1.29m	
	Station 1C : Lower mudflat, near the main channel	1.38m	
Site 2	Station 2A: Upper mudflat	4.50m	Large middle estuarine mudflat, near oyster farming areas.
	Station 2B : Center of the mudflat	4.20m	
	Station 2C : Lower mudflat	1.38m	
Site 4	Station 4A: Upper mudflat	3.30m	
	Station 4B : Lower mudflat	1.37m	
Site 5	Station 5A: Upper mudflat	2.20m	Large middle estuarine mudflat
	Station 5B: Lower mudflat	1.21m	
Site 6	Station 6A: Upper mudflat	2.50m	
	Station 6B: Lower mudflat	1.49m	
Site 7	Mudflat along small auxiliary creak	1.31m	Inner estuary
Site 8	Mudflat in the city of Auray Station 8A: Upper mudflat	2.30m	
	Station 8B: Lower mudflat	1.29m	
Vie estuary			
Site 1	Beach in the mouth immediately outside the estuary	-	Outside the estuary
Site 2	Beach just before the entrance of the estuary	3.35m	
Site 3	Dock for ferry boat	2.00m	Outer estuary, urban area
Site 4	Slipway for pleasure ships	1.82m	
Site 5	Slipway in fishing harbour	2.67m	
Site 6	Dock for touristic boat	1.44m	
Site 7	Large intertidal mudflat Station 7A : Upper mudflat	4.82m	Middle estuary
	Station 7B : Center of the mudflat	4.18m	
	Station 7C : Lower mudflat, near the main channel	1.61m	

Site 8	Station 8A: Upper mudflat	4.21m	Inner estuary
	Station 8B: Lower mudflat, near the main channel	1.15m	
Site 9	Lower mudflat, near main channel	1.22m	
Site 10	Mudflat 200 m before the sluice Station 10A: Upper mudflat	4.86m	
	Station 10B: Lower mudflat, near the main channel	2.24m	

Table S3. Grain size data.

Station	Population 1 (very fine silt)		Population 2 (medium silt)		Population 3 (coarse silt - very fine sand)		Population 4 (medium sand)		% grains < 63 µm	% grains < 8 µm
	mode (µm)	Population %	mode (µm)	Population %	mode (µm)	Population %	mode (µm)	Population %		
Auray										
1A	5.8	42.4	17.6	14.8	64.1	40.2	224.4	2.6	76.6	27.8
1B	6.1	40.0	19.2	9.1	86.3	50.9	256.2	0.1	66.9	24.6
1C	5.8	27.3	18.3	7.3	104.2	60.2	492.6	5.2	49.4	17.2
2A	5.6	47.2	16.3	14.2	48.9	36.0	187.0	2.6	83.0	32.0
2B	5.6	49.6	16.2	12.5	41.7	29.9	115.9	7.9	85.5	33.1
2C	6.0	49.5	20.3	26.4	66.2	21.5	252.7	2.7	83.4	33.1
4A	5.4	36.0	16.9	12.2	79.1	48.6	332.0	3.1	67.0	25.5
4B	5.2	39.5	16.9	11.0	80.7	46.6	353.0	2.9	68.3	28.1
5A	5.1	47.5	15.3	22.3	58.8	27.7	196.2	2.5	83.9	36.9
5B	5.2	46.8	15.7	11.7	53.0	39.4	254.0	2.1	80.4	34.4
6A	5.3	46.2	16.1	11.7	60.1	39.1	213.8	3.0	77.2	32.8
6B	5.0	47.0	16.9	21.1	78.5	29.2	270.3	2.7	79.0	35.6
7	5.0	46.7	12.7	10.7	30.1	30.9	118.1	11.6	84.7	36.3
8A	4.6	36.7	14.1	25.4	65.1	35.5	265.8	2.4	78.5	33.9
8B	4.9	32.0	19.7	23.1	92.9	14.3	284.2	30.7	54.9	24.7
Vie										
3	7.8	59.2			79.3	37.0	296.9	3.7	72.4	31.7
4	6.9	49.2			82.4	48.2	296.8	2.6	66.0	29.0
5	8.4	52.6			68.6	45.4	276.5	2.0	72.9	27.1
6	7.1	51.2			71.5	38.0	247.8	10.8	65.0	29.2
7A	7.0	53.5			59.3	41.3	310.3	5.2	75.0	31.5
7B	6.2	58.0			52.1	37.5	301.7	4.6	79.0	36.4
7C	6.6	57.1			63.6	37.2	297.2	5.6	74.7	34.3
8A	6.6	56.1			58.9	39.7	283.2	4.2	76.3	34.2
8B	7.3	52.0			100.8	47.5	321.1	0.5	63.8	27.8
9	7.3	57.9			98.1	40.2	274.6	1.9	70.2	31.5
10A	6.0	61.1			64.8	38.3	202.9	0.6	79.4	38.2
10B	6.2	66.1			42.2	31.4	224.2	0.9	88.5	43.1

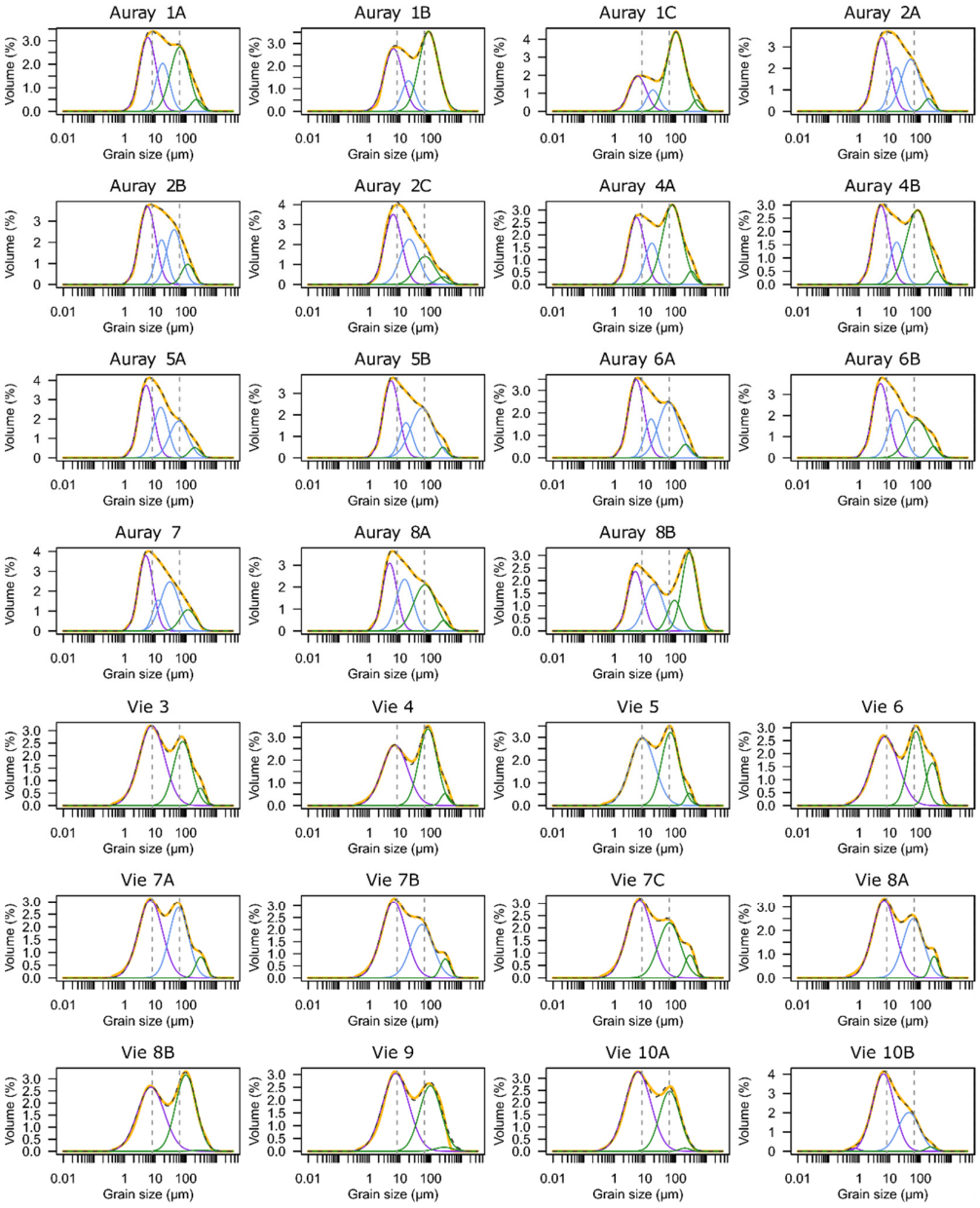

Figure S1. Overall grainsize distribution (yellow dashes curves), and reconstructed grain size populations (solid coloured curves).

Table S4. Measured values of metallic trace elements (in mg/kg of dry sediment).

		V	Cr	Co	Ni	Cu	Zn	As	Sr	Mo	Ag	Cd	Sn	Sb	Ba	Pb	Th	U	% grains < 63 µm
Auray	1A	97.7	76.4	9.0	28.0	61.5	168	16.2	121	2.0	0.3	0.6	6.3	1.0	341	41.8	7.7	3.0	76.6
	1B	82.5	63.9	7.8	23.4	16.2	123	11.4	146	2.0	0.2	0.5	5.2	0.9	412	35.9	5.8	2.7	66.9
	1C	77.1	59.0	7.4	21.8	13.4	107	11.1	159	3.0	0.2	0.4	4.8	0.9	369	32.4	5.5	2.8	49.4
	2A	104	81.8	9.1	30.3	23.1	154	17.1	123	2.7	0.3	0.6	6.5	1.0	295	43.4	9.4	3.3	83.0
	2B	98.7	77.0	8.6	28.5	20.2	139	15.8	137	2.9	0.3	0.5	6.1	1.0	287	41.5	8.8	3.5	85.5
	2C	89.9	71.8	8.0	26.2	18.6	125	16.4	125	2.2	0.3	0.5	5.7	0.9	289	37.4	7.9	3.0	83.4
	4A	86.3	66.0	7.9	24.5	14.6	108	13.3	142	4.4	0.2	0.4	5.2	0.9	358	35.0	6.7	3.3	67.0
	4B	97.9	75.5	8.9	28.1	22.6	146	14.6	122	2.7	0.3	0.5	6.1	1.0	334	41.6	8.2	3.4	68.3

	5A	98.3	79.2	9.1	29.2	25.7	173	18.0	161	1.5	0.4	0.6	7.1	1.0	297	44.4	8.7	3.0	83.9
	5B	103	82.5	9.5	30.7	24.7	170	18.0	133	1.2	0.4	0.6	7.2	1.0	308	46.0	9.2	2.9	80.4
	6A	87.7	71.4	8.4	26.2	21.8	160	17.8	137	1.4	0.4	0.6	6.2	1.0	313	42.6	7.5	2.9	77.2
	6B	89.7	72.6	8.6	27.5	23.3	162	18.2	118	1.3	0.4	0.6	6.2	0.9	277	42.8	8.1	2.8	79.0
	7	106	87.0	10.1	33.4	30.4	196	21.1	120	1.2	0.5	0.7	7.5	1.1	294	50.7	9.9	3.3	84.7
	8A	85.9	71.1	8.4	27.8	25.5	173	19.2	103	1.6	0.4	0.6	6.3	0.9	272	42.5	7.9	3.0	78.5
	8B	48.9	40.3	5.5	15.9	12.7	126	12.2	139	0.6	0.3	0.4	4.6	0.7	470	35.2	4.2	1.9	54.9
Vie	1	33.3	18.1	4.0	12.0	9.4	40	8.4	501	0.3	0.2	0.1	1.6	1.2	293	10.8	2.6	1.1	4.7
	2	22.1	11.6	3.0	7.9	5.0	27	7.4	419	0.9	0.1	0.1	1.0	0.8	241	12.7	1.9	0.8	4.1
	3	70.7	51.7	8.3	22.3	17.8	104	15.5	463	0.8	0.4	0.3	3.8	1.0	213	28.7	5.9	1.7	72.4
	4	73.4	52.5	8.9	22.6	26.5	128	16.7	446	2.4	0.4	0.3	4.0	1.0	218	30.0	6.2	1.7	66.0
	5	82.2	60.3	9.8	24.9	31.4	138	19.3	369	0.9	0.4	0.3	4.7	1.2	245	33.9	6.9	1.9	72.9
	6	84.4	62.8	10.6	28.5	51.3	195	16.4	376	1.3	0.4	0.4	5.8	1.3	287	39.2	7.5	2.2	65.0
	7A	81.7	63.9	10.2	25.1	19.3	127	14.5	324	2.5	0.5	0.3	4.8	1.2	268	35.9	7.3	2.3	75.0
	7B	94.8	68.6	12.6	27.1	22.2	130	16.6	306	1.0	0.5	0.4	4.9	1.3	266	36.1	7.5	2.2	79.0
	7C	79.9	59.8	10.0	24.7	20.8	122	17.5	412	1.0	0.4	0.4	4.7	1.2	266	34.8	7.1	2.0	74.7
	8A	69.0	53.0	9.3	21.3	20.2	114	15.6	321	1.6	0.4	0.3	4.0	1.1	280	31.1	6.4	2.0	76.3
	8B	81.9	64.5	10.2	24.7	22.9	129	17.8	251	1.4	0.5	0.4	5.5	1.3	307	34.4	7.2	2.2	63.8
	9	64.1	50.6	9.1	23.7	19.6	108	14.9	247	0.7	0.9	0.3	3.8	1.1	293	30.1	6.1	1.8	70.2
	10A	102.3	80.1	12.3	30.7	30.5	162	24.0	234	1.0	0.5	0.4	6.1	1.5	314	39.8	9.3	2.3	79.4
	10B	76.7	62.1	9.5	22.8	20.9	121	13.2	175	0.9	0.4	0.3	4.5	1.2	332	32.9	7.2	2.3	88.5
Reference VIVAN 8		119.5	81.9	14.2	43.9	18.8	135	23.4	163	30.2	0.5	0.9	4.5	1.5	310	36.7	10.3	13.4	

Table S5. %C_{org} and $\delta^{13}C$ values in decarbonated samples from Auray and Vie estuaries.

Auray			Vie		
Station	**C_{org} (%)**	**$\delta^{13}C$ (‰)**	**Station**	C_{org} (%)	$\delta^{13}C$ (‰)
1A	1.66	-18.77	3	2.27	-14.31
1B	1.43	-18.27	4	2.08	-15.54
1C	1.53	-17.71	5	2.15	-17.41
2A	2.27	-18.87	6	1.96	-17.73
2B	1.88	-18.84	7A	1.34	-19.11
2C	2.33	-18.04	7B	1.56	-21.00
4A	1.56	-18.69	7C	1.95	-14.96
4B	2.22	-19.35	8A	1.47	-13.58
5A	2.40	-19.93	8B	1.96	-23.20
5B	2.28	-21.08	9	1.51	-22.77
6A	2.15	-21.13	10A	1.72	-24.88
6B	2.17	-21.32	10B	1.16	-19.82
7	2.91	-21.21			
8A	2.93	-22.69			
8B	1.23	-23.86			

Table S6. Auray estuary. Foraminiferal density standardised for 50 cm3. For all stations. Data are presented for the three replicates.

Site	Station	Replicate	0-1 cm total forams / 50 cm3	0-1 cm average / 50 cm3	standard deviation	0-1 cm average / 50 cm3	standard deviation
1	1A	A	424.4	320.9	96.1	75.9	11.1
		B	234.3				
		C	304.1				
	1B	A	1033.9	1081.3	681.3	242.2	252.6
		B	424.9				
		C	1785.0				
	1C	A	1899.2	1693.2	275.2	331.2	181.7
		B	1380.6				
		C	1799.7				
2	2A	A	23.5	26.5	23.3	24.0	11.0
		B	4.8				
		C	51.1				
	2B	A	75.3	33.9	35.9	35.9	35.5
		B	11.7				
		C	14.5				
	2C	A	778.9	618.8	153.0	62.2	76.8
		B	474.1				
		C	603.4				
4	4A	A	700.7	655.1	141.0	116.3	66.1
		B	496.9				
		C	767.6				
	4B	A	427.8	309.9	104.4	102.0	61.6
		B	229.5				
		C	272.3				
5	5A	A	237.7	279.0	36.2	9.9	6.0
		B	305.5				
		C	293.7				
	5B	A	339.3	310.8	28.7	50.0	15.5
		B	282.0				
		C	311.0				
6	6A	A	816.5	810.0	23.3	14.9	12.9
		B	829.4				
		C	784.2				
	6B	A	1067.1	901.2	145.6	16.2	13.1
		B	794.8				
		C	841.8				
7	7	A	125.8	138.7	11.4	2.3	2.0
		B	147.2				
		C	143.1				
8	8A	A	180.4	114.3	57.3	0.7	0.7
		B	80.2				
		C	82.2				
	8B	A	398.2	183.2	191.0	0.5	0.4
		B	33.2				

	C	118.2

Table S7. Vie estuary. Foraminiferal density standardised for 50 cm3. For all stations. Data are presented for the three replicates.

Station	Replicate	0-1 cm total forams / 50 cm³	0-1 cm average / 50 cm3	standard deviation	0-1 cm average / 50 cm3	standard deviation
	A	434.0				
3	B	591.6	598.1	167.3	41.0	44.1
	C	768.5				
	A	431.3				
4	B	1025.6	623.9	348.0	36.9	37.6
	C	414.7				
	A	184.5				
5	B	89.8	169.6	73.4	34.8	26.1
	C	234.3				
	A	427.1				
6	B	667.2	628.3	184.9	23.3	15.5
	C	790.6				
	A	1721.6				
7A	B	2095.5	1744.2	340.6	0.0	0.0
	C	1415.4				
	A	1152.1				
7B	B	934.4	1283.4	430.0	3.7	3.2
	C	1763.8				
	A	981.4				
7C	B	1036.7	906.1	180.4	38.1	22.9
	C	700.3				
	A	937.2				
8B	B	1150.0	1079.1	122.9	84.8	37.7
	C	1150.0				
	A	1981.5				
8A	B	1515.0	1799.5	249.6	0.0	0.0
	C	1902.0				
	A	591.6				
9	B	975.9	889.3	265.2	37.8	28.0
	C	1100.3				
	A	239.8				
10B	B	163.1	202.5	38.4	9.7	6.0
	C	204.6				
	A	1094.7				
10A	B	919.2	883.3	231.6	0.2	0.4
	C	635.8				

Table S8. Auray estuary. Relative frequencies of all major species (at least 1.0% for the average of the three replicates at one of the stations). Average values are given for the relative frequencies in the three replicates.

Station	*Acostata mariei*	*Ammobaculites agglutinans*	*Ammotium salsum*	*Eggerelloides scaber*	*Morulaeplecta bulbosa*	*Trochammina inflata*	*Miliammina fusca*	*Quinqueloculina oblonga*	*Ammonia tepida* group	*Aubignyna perlucida*	*Elphidium decipiens*	*Elphidium margaritaceum*	*Elphidium oceanense*	*Elphidium selseyense*	*Haynesina depressula*	*Haynesina germanica*	Others
1A	0.0	0.0	0.0	0.7	0.0	0.1	0.0	0.3	11.2	0.0	0.2	2.4	2.8	0.5	0.0	81.6	0.2
1B	0.0	0.0	0.0	2.0	0.0	0.0	0.0	4.8	13.2	0.0	0.6	9.4	14.8	1.3	0.5	53.0	0.4
1C	0.0	0.2	0.0	3.0	0.1	0.0	0.2	6.3	10.8	0.0	1.0	17.8	9.9	0.4	3.3	46.1	1.0
2A	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	95.8	0.0
2B	2.0	1.0	0.3	0.0	1.6	0.0	0.0	0.3	2.5	1.3	0.0	0.0	0.0	0.0	0.3	90.1	0.6
2C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	16.1	1.1	0.2	0.9	5.8	0.1	0.0	75.1	0.1
4A	0.0	4.1	4.6	0.4	0.0	0.0	0.0	2.8	3.6	0.0	0.1	0.2	0.5	0.0	0.0	83.6	0.1
4B	0.1	2.4	0.2	0.4	0.0	0.0	0.1	0.7	13.1	0.0	0.0	0.1	0.6	0.0	0.0	82.2	0.1
5A	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	98.0	0.0
5B	0.0	5.0	1.0	0.5	0.0	0.1	0.0	2.2	11.9	0.0	0.0	0.2	0.7	0.7	0.0	77.1	0.6
6A	0.0	0.8	1.2	0.0	0.0	0.0	0.0	0.3	2.8	0.7	0.0	0.0	0.1	0.1	0.0	94.1	0.0
6B	0.0	3.4	1.9	0.7	0.0	0.0	0.0	0.7	10.4	0.2	0.0	0.2	0.5	0.3	0.1	81.3	0.3
7	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	12.4	0.0	0.0	0.3	2.7	0.0	0.0	79.7	0.5
8A	0.1	2.8	23.3	0.0	0.0	0.4	1.1	0.0	17.8	0.0	0.0	0.0	3.5	0.0	0.0	50.0	0.9
8B	0.3	5.9	81.1	0.0	0.0	7.9	1.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.2

Table S9. Vie estuary. Relative frequencies of all major species (at least 1.0% for the average of the three replicates at one of the stations). Average values are given for the relative frequencies in the three replicates.

Station	***Quinqueloculina jugosa***	***Quinqueloculina oblonga***	***Ammonia tepida* group**	***Elphidium magellanicum***	***Elphidium oceanense***	***Elphidium selseyense***	***Elphidium williamsoni***	***Haynesina germanica***	**Others**
3	2.3	1.5	4.0	0.6	0.3	50.2	1.2	38.7	1.2
4	5.7	4.9	3.7	1.7	0.3	68.5	0.2	14.1	1.2
5	1.2	1.8	1.5	0.3	0.0	66.2	0.1	28.4	0.6
6	0.8	0.7	6.2	0.1	0.1	9.9	0.1	81.7	0.5
7A	0.3	0.3	6.2	0.0	0.7	0.1	0.2	92.2	0.1
7B	1.8	0.3	5.7	0.0	0.1	1.7	0.1	90.0	0.0
7C	2.6	2.1	16.3	0.1	0.5	8.5	0.3	69.5	0.3
8B	5.1	1.6	23.0	0.0	1.5	12.2	0.0	56.4	0.0
8A	1.2	1.8	11.7	0.0	2.7	0.0	0.3	82.3	0.2

9	5.8	1.3	42.4	0.0	2.5	5.5	0.2	42.3	0.0
10B	7.3	1.6	49.8	0.0	0.9	0.2	0.2	39.7	0.0
10A	0.8	0.2	35.2	0.0	3.2	0.0	0.2	60.4	0.3

Table S10. Marine Influence Index (MII) values for the studied stations.

	Station	MII		Station	MII
Auray	1A	0.48	**Vie**	3	0.69
	1B	0.67		4	0.71
	1C	0.65		5	0.58
	2A	0.08		6	0.72
	2B	0.17		7A	0.19
	2C	0.57		7B	0.31
	4A	0.25		7C	0.65
	4B	0.43		8A	0.26
	5A	0.28		8B	0.64
	5B	0.37		9	0.58
	6A	0.21		10A	0.11
	6B	0.28		10B	0.36
	7	0.24			
	8A	0.13			
	8B	0.17			

Table S11. Eigenvalues, % of variance and species scores of the PCA based on relative frequencies of all major species (at least 1.0% for the average of the three replica at one of the stations).

Axis	PCA1	PCA2	PCA3
Eigenvalue	890.4	356.2	236.0
% of variance explained	58.2%	23.3%	15.4%
Acostata mariei	0.02	-0.01	-0.03
Ammobaculites agglutinans	-0.03	-0.32	-0.29
Ammonia tepida group	-0.63	**-1.38**	**4.44**
Ammotium salsum	**-2.64**	**-4.16**	**-2.92**
Aubignyna perlucida	0.03	0.00	-0.01
Eggerelloides scaber	0.00	-0.02	0.03
Elphidium decipiens	0.00	-0.01	0.01
Elphidium magellanicum	-0.08	0.08	-0.02
Elphidium margaritaceum	-0.11	-0.12	0.17
Elphidium oceanense	-0.07	-0.24	0.41
Elphidium selseyense	**-4.77**	**5.02**	**-0.97**
Elphidium williamsoni	-0.03	0.02	0.01
Haynesina depressula	-0.02	-0.02	0.02
Haynesina germanica	**9.26**	**1.30**	**-1.01**
Miliammina fusca	-0.07	-0.11	-0.07
Morulaeplecta bulbosa	0.02	0.00	-0.01
Quinqueloculina jugosa	-0.35	0.14	0.43
Quinqueloculina oblonga	-0.20	0.15	0.09
Trochammina inflata	-0.26	-0.37	-0.28

Table S12. Results of Spearman correlation test between all dominant species (>5%) and environmental parameters. Values correspond to R, *ns* means that the relation is not significant, * that the p.value is < 0.05 and ** that the p.value is < 0.01. Blue indicates negative correlations, red positive correlations and grey non-significant correlations.

		MII	Emergence time	Normalised distance to sea	< 63um	C_{org}(%)
Ammobaculites agglutinans	2 estuaries	x	x	x	x	x
	Auray	−0.47 ns	0.01 ns	−0.53 *	−0.21 ns	−0.11 ns
	Vie	x	x	x	x	x
Ammonia tepida group	2 estuaries	0.17 ns	−0.32 ns	−0.15 ns	−0.1 ns	0.09 ns
	Auray	0.45 ns	−0.39 ns	0.12 ns	−0.05 ns	0.34 ns
	Vie	−0.38 ns	−0.05 ns	−0.93 **	0.35 ns	−0.68 *
Ammotium salsum	2 estuaries	x	x	x	x	x
	Auray	−0.59 *	−0.06 ns	−0.88 **	−0.03 ns	0.1 ns
	Vie	x	x	x	x	x
Elphidium margaritaceum	2 estuaries	x	x	x	x	x
	Auray	0.83 **	−0.44 ns	0.58 *	−0.33 ns	−0.27 ns
	Vie	x	x	x	x	x
Elphidium oceanense	2 estuaries	0.16 ns	−0.21 ns	−0.05 ns	−0.13 ns	−0.06 ns
	Auray	0.68 **	−0.46 ns	0.36 ns	−0.33 ns	0.01 ns
	Vie	-0.47 ns	0.12 ns	−0.79 **	0.25 ns	−0.55 ns
Elphidium selseyense	2 estuaries	x	x	x	x	x
	Auray	x	x	x	x	x
	Vie	0.81 **	−0.61 *	0.75 *	−0.74 *	0.84 **
Haynesina germanica	2 estuaries	−0.43 *	0.47 *	−0.17 ns	0.17 ns	0.40 *
	Auray	−0.31 ns	0.68 *	0.1 ns	0.49 ns	0.23 ns
	Vie	-0.41 ns	0.27 ns	−0.25 ns	0.24 ns	−0.54 ns
Quinqueloculina jugosa	2 estuaries	x	x	x	x	x
	Auray	x	x	x	x	x
	Vie	0.34 ns	−0.54 ns	−0.19 ns	−0.11 ns	−0.06 ns
Quinqueloculina oblonga	2 estuaries	0.73 **	−0.38 *	0.47 *	−0.23 ns	−0.47 *
	Auray	0.75 **	−0.3 ns	0.5 ns	−0.4 ns	−0.36 ns
	Vie	0.48 ns	−0.38 ns	0.34 ns	−0.33 ns	0.33 ns

Table S13. Ecological characteristics of the dominant species of our dataset.

Ammonia tepida	*Ammonia tepida* is considered as one of the dominant species in intertidal sediments [98]. It is characteristic of lagoons, estuaries and inner shelfs [66] and known to be tolerant to all kinds of stressed conditions (e.g, low salinity, organic input, hypoxic conditions) [84,99]. *A. tepida* is considered as 2nd order opportunist by Jorissen et al. [19], and as a 3rd order opportunist by Bouchet et al. [25].
Haynesina germanica	*Haynesina germanica* is a major species in estuarine areas and is considered as extremely euryhaline [66,82]. It is present in polluted [35,90] as well as unpolluted estuaries [27,81]. *H. germanica* is considered as a 3rd order opportunist by Jorissen et al. [19], and Bouchet et al. [25].
Elphidium margaritaceum	*Elphidium margaritaceum* is dominant in estuary mouths, nearshore areas and marine areas [66,83,94]. It is considered as a sensitive species by Bouchet et al., [25].
Elphidium oceanense	*Elphidium oceanense* is a brackish to marine species, commonly found in estuaries, estuary mouths and nearshore areas [66]. This species is considered as a 3rd order opportunist by Jorissen et al. [19] and Bouchet et al. [25].

Elphidium selseyense	*Elphidium selseyense* is an inner shelf species, tolerant of brackish conditions [33,66,82]. This species is considered as a sensitive species by Bouchet et al., [25].
Quinqueloculina oblonga	*Quinqueloculina oblonga* is commonly found in estuary mouths and nearshore areas [27,66]. This species is considered as a 3rd order opportunist by Jorissen et al [19] and as a 1st order opportunist by Bouchet et al [25].
Quinqueloculina jugosa	*Q. jugosa* is considered as a 1st order opportunist by Bouchet et al [25].
Ammotium salsum	*Ammotium salsum* is widespread in brackish environments [100,101] and has a preference for environments with a salinity comprised between 10 and 20 [85]. It is especially common in salt marshes [28,69]. *A. salsum* was found in environments subjected to stressful conditions (e.g., high temperature variations, low oxygen in sediment, elevated trace metal) and considered as a very robust species [95]. It favours substrates rich in organic matter [85].
Ammobaculites agglutinans	*Ammobaculites agglutinans* is commonly found in inner part of estuaries and salt marshes [102] and tolerates a wide range of temperature and salinity [85]. It favours substrates rich in organic matter [85].
Trochammina inflata	*Trochammina inflata* is predominant in brackish tidal marshes [31,66,83]. It tolerates a high environmental variability, including periods of low oxygen availability [66]. *T. inflata*, like others salt marsh species (e.g., *A. salsum* and *A. agglutinans*), shows a strong correlation with high organic carbon levels, even in completely natural conditions [32]. For this reason, this species is not assigned to an ecological group by Bouchet et al. [25].