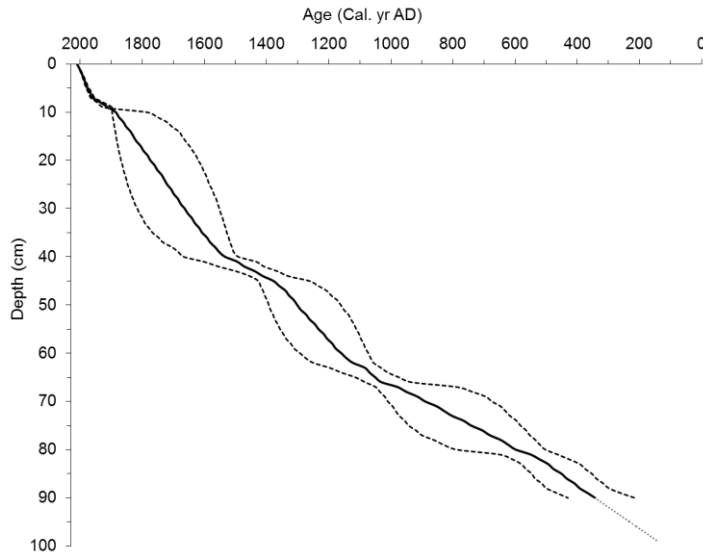


RECORDS FROM MARSH FORAMINIFERA AND GRAPEVINE GROWING  
SEASON TEMPERATURES REVEAL THE HYDRO-CLIMATIC EVOLUTION OF  
THE MINHO REGION (NW PORTUGAL) FROM 1856–2009

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Appendix 1. Age model for the core FCPw1 and estimated  $2\sigma$  errors, based on six AMS- $^{14}\text{C}$  dates, performed on total organic sediment, and  $^{210}\text{Pb}$  chronology. The data interpolation was obtained with Bchron 3.2 software (after Moreno et al., 2014).



| Depth (cm) | $^{210}\text{Pb}_{\text{Excess}}$ | error | $^{137}\text{Cs}$ | error |
|------------|-----------------------------------|-------|-------------------|-------|
| 0.5        | 328.8                             | 38.3  |                   |       |
| 1.5        | 250.7                             | 29.7  |                   |       |
| 2.5        | 166.1                             | 20.9  |                   |       |
| 3.5        | 121.1                             | 16.4  | 16.7              | 1.7   |
| 4.5        | 113.6                             | 15.6  | 17.7              | 1.7   |
| 5.5        | 108.9                             | 15.3  | 20.0              | 1.7   |
| 6.5        | 88.2                              | 13.0  | 28.5              | 1.7   |
| 7.5        | 125.9                             | 16.8  | 40.5              | 1.3   |
| 8.5        | 66.8                              | 10.9  | 74.3              | 2.7   |
| 9.5        | 30.5                              | 7.4   | 45.7              | 1.7   |
| 10.5       | 12.5                              | 5.6   |                   |       |
| 11.5       | 5.0                               | 4.9   |                   |       |
| 12.5       | 2.4                               | 4.6   |                   |       |
| 13.5       | 2.1                               | 4.6   |                   |       |

$^{210}\text{Pb}_{\text{Excess}}$  and  $^{137}\text{Cs}$  content (Bq kg $^{-1}$ )

| Sample | Depth (cm) | $\delta^{13}\text{C}$ ‰ | Conventional radiocarbon age | $\Delta^{14}\text{C}$ ‰ | Calibrated years AD (2 Sigma range) |
|--------|------------|-------------------------|------------------------------|-------------------------|-------------------------------------|
| CM 41  | 40-41      | -26.7                   | 380 ± 30 BP                  | -46.20 ± 3.6            | 1490 to 1666                        |
| CM 45  | 44-45      | -26.8                   | 650 ± 35 BP                  | -84.57 ± 3.9            | 1330 to 1453                        |
| CM 64  | 63-64      | -25.9                   | 1010 ± 50 BP                 | -122.49 ± 1.9           | 1032 to 1197                        |
| CM 67  | 66-67      | -25.9                   | 1030 ± 34 BP                 | -124.97 ± 1.9           | 934 to 1082                         |
| CM 82  | 81-82      | -25.8                   | 1570 ± 40 BP                 | -181.66 ± 1.9           | 463 to 650                          |
| CM 91  | 90-91      | -27.2                   | 1760 ± 30 BP                 | -196.80 ± 3.0           | 215 to 429                          |

Radiocarbon ages data determined in the Laboratory of Beta Analytic Inc. (AMS Standard Delivery)

APPENDIX 2. Dead foraminiferal assemblage percentages from FCPwAR Caminha tidal marsh core.

| Depth (cm) | Age (cal. AD) | <i>H. manilaensis</i> | <i>T. salsa</i> | <i>M. fusca</i> + <i>Miliammina</i> spp. | <i>J. macrescens</i> | <i>T. inflata</i> | <i>P. limnets</i> | <i>H. wiberti</i> | <i>T. comprimata</i> | <i>S. lobata</i> | <i>P. guaraitbaensis</i> | <i>P. ipohialina</i> | Brackish to "Normal" Salinity group | Low Salinity group |
|------------|---------------|-----------------------|-----------------|--|----------------------|-------------------|-------------------|-------------------|----------------------|------------------|--------------------------|----------------------|-------------------------------------|--------------------|
| 0.0        | 2010          | 18.4                  | 60.5            | 4.1                                      | 4.1                  | 8.8               | 2.7               |                   |                      |                  |                          | 0.0                  | 15.6                                | 83.0               |
| 0.5        | 2007          | 15.6                  | 43.8            | 8.6                                      | 1.6                  | 18.8              | 1.6               | 6.3               | 0.8                  |                  |                          | 1.6                  | 30.5                                | 68.0               |
| 1.0        | 2005          | 14.3                  | 46.3            | 4.1                                      |                      | 15.0              | 0.7               | 12.2              |                      |                  |                          | 0.7                  | 28.6                                | 64.6               |
| 1.5        | 2002          | 16.1                  | 41.6            | 9.4                                      | 0.7                  | 19.5              | 0.7               | 8.1               |                      |                  |                          |                      | 28.9                                | 67.1               |
| 2.0        | 1998          | 17.7                  | 42.6            | 5.7                                      |                      | 12.1              | 0.7               | 13.5              | 0.7                  | 2.1              |                          |                      | 29.1                                | 66.0               |
| 2.5        | 1995          | 12.3                  | 46.2            | 17.7                                     |                      | 10.0              |                   | 9.2               |                      | 1.4              | 1.5                      |                      | 20.8                                | 76.2               |
| 3.0        | 1992          | 17.4                  | 47.1            | 8.7                                      |                      | 7.2               |                   | 7.2               | 1.4                  | 1.4              |                          |                      | 18.8                                | 73.2               |
| 3.5        | 1988          | 23.8                  | 35.1            | 13.2                                     |                      | 8.6               | 0.7               | 10.6              | 0.7                  | 0.7              |                          | 0.7                  | 21.9                                | 72.2               |
| 4.0        | 1986          | 30.7                  | 42.5            | 0.8                                      |                      | 9.4               |                   | 4.7               | 3.9                  |                  |                          |                      | 18.1                                | 74.0               |
| 4.5        | 1983          | 14.8                  | 50.0            | 7.7                                      |                      | 5.6               |                   | 13.4              | 0.7                  |                  |                          | 3.5                  | 23.2                                | 72.5               |
| 5.0        | 1980          | 14.6                  | 46.0            | 4.4                                      |                      | 11.7              |                   | 15.3              | 1.5                  |                  |                          | 0.7                  | 29.2                                | 65.0               |
| 5.5        | 1976          | 31.4                  | 32.1            | 6.4                                      |                      | 12.1              |                   | 7.9               | 1.4                  |                  |                          |                      | 21.4                                | 70.0               |
| 6.0        | 1972          | 19.9                  | 46.8            | 5.0                                      |                      | 5.0               | 2.1               | 14.9              |                      |                  |                          | 2.1                  | 26.2                                | 71.6               |
| 6.5        | 1967          | 9.1                   | 50.8            | 6.8                                      |                      | 13.6              | 1.5               | 9.1               | 0.8                  |                  | 2.3                      |                      | 28.0                                | 66.7               |
| 7.0        | 1963          | 14.0                  | 45.7            | 3.1                                      |                      | 15.5              | 2.3               | 12.4              | 3.1                  |                  | 0.8                      |                      | 34.9                                | 62.8               |
| 7.5        | 1960          | 44.6                  | 33.7            | 1.0                                      |                      | 12.9              |                   | 0.0               |                      |                  | 2.0                      |                      | 15.8                                | 78.2               |
| 8.0        | 1947          | 28.7                  | 20.6            |  |                      | 5.9               |                   | 29.4              | 1.5                  |                  |                          |                      | 45.6                                | 49.3               |
| 8.5        | 1934          | 35.3                  | 10.5            | 0.8                                      |                      | 8.3               | 12.8              | 22.6              | 2.3                  |                  | 3.8                      |                      | 49.6                                | 46.6               |
| 9.0        | 1917          | 67.0                  | 9.8             | 1.8                                      |                      | 3.6               | 8.9               |                   | 0.9                  | 0.9              |                          |                      | 15.2                                | 78.6               |
| 9.5        | 1900          | 43.5                  | 18.4            | 2.7                                      |                      | 7.5               | 10.2              | 8.8               |                      | 5.4              |                          |                      | 32.0                                | 64.6               |
| 10.0       | 1893          | 36.2                  | 12.3            | 3.6                                      |                      | 8.0               | 22.5              | 4.3               | 0.7                  | 5.1              | 0.7                      |                      | 41.3                                | 52.2               |
| 10.5       | 1885          | 47.4                  | 13.9            |  |                      | 7.3               | 16.1              | 10.9              |                      | 0.7              | 2.2                      |                      | 37.2                                | 61.3               |
| 11.0       | 1881          | 41.3                  | 13.5            | 5.6                                      |                      | 3.2               | 7.1               | 13.5              | 3.2                  | 1.6              | 3.2                      |                      | 31.7                                | 60.3               |
| 11.5       | 1876          | 26.5                  | 27.2            | 0.7                                      |                      | 6.6               |                   | 21.3              |                      | 3.7              | 3.7                      | 1.5                  | 37.5                                | 54.4               |
| 12.0       | 1869          | 15.2                  | 34.1            | 2.9                                      |                      | 5.8               | 1.4               | 14.5              | 2.9                  | 3.6              | 1.4                      |                      | 41.3                                | 52.2               |
| 12.5       | 1861          | 6.2                   | 43.1            | 0.8                                      |                      | 8.5               | 10.0              | 18.5              | 1.5                  |                  | 6.2                      | 2.3                  | 46.9                                | 50.0               |
| 13.0       | 1857          | 5.7                   | 30.1            |  |                      | 13.8              | 12.2              | 24.4              | 2.4                  | 3.3              | 1.6                      | 0.8                  | 58.5                                | 35.8               |
| 13.5       | 1852          | 8.3                   | 28.3            |  |                      | 11.7              | 8.3               | 15.8              | 1.7                  | 3.3              | 11.7                     | 2.5                  | 55.0                                | 36.7               |
| 14.0       | 1845          | 3.7                   | 20.6            | 0.7                                      |                      | 13.2              | 21.3              | 20.6              | 5.1                  | 4.4              | 5.1                      | 0.7                  | 70.6                                | 25.0               |
| 14.5       | 1838          | 4.0                   | 18.3            |  |                      | 10.3              | 17.5              | 23.8              | 1.6                  | 5.6              | 7.1                      | 6.3                  | 72.2                                | 22.2               |
| 15.0       | 1833          | 2.5                   | 11.5            | 2.5                                      |                      | 15.6              | 7.4               | 40.2              |                      | 4.9              | 0.8                      | 7.4                  | 76.2                                | 16.4               |
| 15.5       | 1829          | 3.1                   | 15.3            | 2.3                                      |                      | 11.5              | 6.1               | 39.7              | 1.5                  | 6.1              | 2.3                      | 6.1                  | 73.3                                | 20.6               |
| 16.0       | 1824          | 1.5                   | 18.5            | 0.7                                      |                      | 14.1              | 8.1               | 34.8              | 5.9                  | 5.9              | 1.5                      | 4.4                  | 74.8                                | 20.7               |

### APPENDIX 3. Systematic list of Caminha tidal marsh foraminiferal species, including ecological distribution synthesis and plates.

Systematic list of Caminha tidal marsh foraminiferal species, including ecological distribution synthesis and plates.

Most of foraminiferal species living in brackish environments are agglutinated forms regarded as typical of salt marshes (e.g., Phleger, 1970; Murray, 1991, 2006; Sen Gupta, 2002).

This appendix intends to illustrate and describe their general ecology, listing the 11 agglutinated most representative species of the Caminha tidal marsh (Minho estuary). Generic names are in accordance with Loeblich and Tappan (1988) and are listed alphabetically.

#### ***Haplophragmoides manilaensis* Andersen, 1953; Plate I, fig. 2**

1953 *Haplophragmoides manilaensis* Andersen, p. 22, pl. 4, figs 7–8.

1957 *Haplophragmoides bonplandi* Todd and Brönnimann, p. 23, pl. 2.

1980 *Haplophragmoides bonplandi* Todd and Brönnimann, 1957 – Scott and Medioli, p. 40, pl. 2, Fig. 4–5.

**General ecology:** Interspecific variability in this species is wide and an intergradational series can be observed between *H. manilaensis* and *Haplophragmoides wilberti*, as described by De Rijk (1995a). Its presence is associated to low-saline conditions, usually above mean high water marsh zones. Several studies indicate that the distribution of *H. manilaensis* is controlled by local salinity conditions, with it favouring brackish environments at the rear of marshes or lower elevation areas associated with freshwater seeps (Scott and Medioli, 1980; Scott and Leckie, 1990; De Rijk, 1995a, b; De Rijk and Troelstra, 1997). Some sites, with elevations above mean highest high water (MHHW), are characterized by the dominance of *H. manilaensis* (Cahill et al., 2015). The Caminha high marsh zone is dominated by the *H. manilaensis* (20% to 96%) association, which can also include *Haplophragmoides* sp. (up to 28%) and a strong presence of *P. limnetis* (up to 68%). This association ranges in elevation between mean high water (MHW) and mean high-water spring (MHWS) (Fatela et al., 2009a).

#### ***Haplophragmoides wilberti* Andersen, 1953; Plate I, fig. 3**

1953 *Haplophragmoides wilberti* Andersen, p. 21, pl. 2, figs 5–6, pl. 3, figs 9–16.

1999 *Haplophragmoides wilberti* Andersen, 1953 – Hayward et al., pl. 1, figs 25–26

**General ecology:** It is generally common to abundant in brackish salt marshes associated with decreasing salinity conditions, living intertidally, above mean sea level and most abundantly above mean high water. This species is dominant in brackish high marshes from New Zealand (Hayward et al., 1999, 2004) and Alve and Murray (1999) reported its presence under a salinity range of 10–27‰, in marginal marine environments of southern Scandinavia. In

Caminha tidal marsh *H. wilberti* shows always a subsidiary occurrence in the high marsh zone, extending its presence to the upper part of low marsh (Fatela et al., 2009a).

***Jadammina macrescens* (Brady, 1870); Plate II, figs 5a, b**

1870 *Trochammina inflata* (Montagu) var. *macrescens* Brady, p. 290, pl. 11, figs 5a–c.

1938 *Jadammina polystoma* Bartenstein and Brand, p. 381, text–figs 1–3.

1950 *Trochammina macrescens* Brady – Phleger and Walton, p. 281, pl. 2, figs 6–7.

1971 *Jadammina macrescens* (Brady) – Murray, p. 41, pl. 13, figs 1–5.

**General ecology:** *J. macrescens* is a widely distributed species, with a presence common to abundant in high marshes above MHW, where moderate to high salinity conditions prevails, but also may occur in adjacent intertidal marginal marine environments (Murray, 2013). It shows a high ability to adapt to various conditions and to occupy any environment fast although, it prefers the more marine habitats of the salt marshes with higher salinities (De Rijk, 1995a). After Hayward et al., (1999) their associations –*Trochammina*, *Jadammina*, *Trochammina–Elphidium*– are high salinity–related above mean high water zones. However in marginal marine southern Scandinavia tolerates a range of salinity from 10 to 28‰ (Alve and Murray, 1999). Being one of the most tolerant species to subaerial exposure, its relative abundance is very useful in sea–level change studies. In fact, its distribution reflects the elevation of the depositional environment in relation to the highest high water level, where it may represent 100% of the foraminiferal assemblages (Scott and Medioli, 1978, 1980). *Jadammina macrescens* is limited to an episodic presence in surface sediments of the Caminha tidal marsh, but it is dominant in the Lima estuary (Fatela et al., 2007, 2009a) and in the high marshes of the SW Portuguese coast, where it can reach codominance even at the low marsh zone (Fatela et al., 2009b, and authors unpublished data). It was also recorded by Camacho et al. (2015) in a marsh of the Guadiana estuary (SE Portuguese coast).

***Miliammina fusca* (Brady, 1870); Plate II, fig. 2a, b**

1870 *Quinqueloculina fusca* Brady, p. 286, pl. 11, figs 2a–c.

2006 *Miliammina fusca* (Brady) – Horton and Edwards, p. 68, pl. 1, figs 5a–b.

**General ecology:** *Miliammina fusca* is a very common species in the upper to middle estuary channels and tidal flats and dominant in most salt marshes, often expanding its presence in marine marginal environments (e.g., Hayward et al., 1999; Murray, 2013). This cosmopolitan species dominates the continental end–member at the referred paralic environments, and is associated with direct freshwater influence (e.g., Debenay and Guillou, 2002). It's a wide range euryhaline species that may tolerate salinities of <1–35‰ (Murray, 2013). De Rijk, 1995b found no correlation between its abundance and salinity (De Rijk, 1995b), but Debenay et al. (2002, 2004) found it more abundant in low salinity areas in French Guiana and it seems characteristic of low salinity estuaries to Hayward et al. (2004). Under temperature and salinity experimental conditions it grew at all salinities tested (12‰, 22‰, 36‰), but was most abundant at salinity 12‰ and it did least well at 12°C (Goldstein and Alve, 2011). In Canada it is considered a cool

tolerant species (Scott and Medioli, 1980). It is regarded as an indicator of the low-mid marsh zone characteristic of the daily-flooded salt marsh areas (De Rijk, 1995a; Varekamp et al., 1992) and the most ubiquitous agglutinated shallow-water species (Murray and Alve, 1999). The brackish low marsh studied in Caminha, is essentially a *M. fusca* zone, but can be subdivided in an IIA upper part, where it is followed by *Pseudothurammia limnetis*, and in an IIB lower part defined by a subsidiary presence of *Psammospaera* sp. (Fatela et al., 2009a). In the Lima estuary it is codominant in the assemblages with *Ammobaculites* spp. from flats and with *J. macrescens* and *T. inflata* from low to high marsh transition at salinities ranging from 1.1‰ to 21‰ (Fatela et al., 2009b). Mentioned as one of the most ubiquitous agglutinated species in the Guadiana estuary (SE Portuguese coast), dominates the mid-low environments in the upper reaches of the estuary (Camacho et al., 2015).

***Paratrochammia (Lepidoparatrochammia) guaratibaensis* Brönnimann, 1986; Plate II, fig. 3**

2002 *Paratrochammia guaratibaensis* Brönnimann, 1986 – Debenay et al., p. 531, pl. 2, figs 11–14.

**General ecology:** It is a brackish species that compose the dominant association, with *T. inflata*, in the upper intertidal zone, at the transition to dry fields in mangrove swamps of French Guiana (Debenay et al., 2002).

***Polysaccammia ipohalina* Scott, 1976; Plate II, Fig. 6**

1976 *Polysaccammia ipohalina* Scott, p. 318, pl. 2, figs 1–4.

1980 *Polysaccammia ipohalina* Scott, 1976 – Scott and Medioli, p. 38, pl. 2, figs 8–9.

**General ecology:** It has a low occurrence (less than 1%) in surface marsh sediments of both NW and SW Portuguese estuaries. It can be seen associated with low salinity indicators like *H. manilaensis* (e.g., Semensatto Junior, 2006) or equally in association with *J. macrescens* and *T. inflata*, like in Guadiana's southeast Portugal estuary (e.g., Camacho et al., 2015). However, and following Scott (1976), *P. ipohalina* appears to be limited to brackish-water marshes and its occurrence with other marsh species such as *T. inflata* and *J. polystoma* should indicate a brackish marsh environment in subsurface sediments. In fact, in Caminha salt marsh, *P. ipohalina* gets its greatest relevance in the FCPwAR core sediments, reaching 18% of the assemblages, ca. –17 cm, in association with *H. manilaensis* and *T. salsa*, two low salinity indicators.

***Pseudothurammia limnetis* (Scott e Medioli, 1980); Plate I, figs 6a, b**

1980 *Thurammia ? limnetis* Scott and Medioli, p. 43, pl. 1, figs 1–3.

1995a *Pseudothurammia limnetis* (Scott and Medioli) – De Rijk, p. 29, pl. 1, figs 15–16.

**General ecology:** It is a common species in salt marsh areas above mean high water (De Rijk, 1995a), but also occurs in low abundance in the lowered salinity upper reaches of enclosed harbours and tidal flats of New Zealand (Hayward et al., 1999). *Pseudothurammia limnetis* revealed an important contribution to the characterization of IB and IA2 subzones of high marsh from present brackish environments of Caminha tidal marsh. Its occurrence can represent up to 68% of living assemblage under a possible optimum of salinity between 8‰ and 14‰, strongly

contrasting with published data, where *P. limnetis* tends to be associated to higher salinity values and always in low proportions. This unusual dominance under such environmental conditions was seen as a new ecological data of *P. limnetis*. Its dominance at the Caminha high marsh must also be stressed because no previous record of *P. limnetis* was found in the European coastal environments (Moreno et al., 2006). That dominance in the Caminha high marsh, is shared with the *H. manilaensis* (20% to 96%) association, which can also include up to 28% of *Haplophragmoides* sp. (Moreno et al., 2006; Fatela et al., 2009a). This association ranges in elevation between MHW and MHWS (Fatela et al., 2009a). This species occurs in low abundance (<2%) in the SW Portuguese marshes at the middle to lower estuaries (authors unpublished data).

***Siphotrochammina lobata* Saunders, 1957; Plate II, fig. 4**

1957 *Siphotrochammina lobata* Saunders, p. 9–10, pl. 3, figs 1–2.

1992 *Siphotrochammina lobata* Saunders, 1957 – Brönnimann et al., p. 31, pl. 4, figs 1–2.

1995a *Siphotrochammina lobata* Saunders, 1957 – De Rijk, p. 33, pl. 3, figs 9, 11–13.

**General ecology:** This primarily marsh/ mangal species is found from north Carolina, USA, to French Guiana, with marginal marine occurrences in Tobago and Brazil (Murray, 2013). Its distribution from high to upper marsh, showed a slight positive correlation with salinity (De Rijk, 1995a). *Siphotrochammina lobata* is referred in association with *A. mexicana* and *H. wilberti* as representative of the high– and intermediate–salinity marshes (Culver and Horton, 2005). This species tend to occur in surface sediments mainly with percentages lower than 5%, but it may however be codominant in the high marsh associations, with *T. inflata* and *J. macrescens* in the NW and SW Portuguese marshes.

***Tiphotrocha comprimata* (Cushman and Brönnimann, 1948); Plate I, figs 5a,b**

1948a *Trochammina comprimata* Cushman and Brönnimann, p. 41, pl. 8, figs 1–3.

2006 *Tiphotrocha comprimata* (Cushman and Brönnimann) – Horton and Edwards p. 69, pl. 2, figs a–e.

**General ecology:** It is mainly a marsh species found only in the Atlantic, from southern Scandinavia to Portugal and from Canada to Brazil (Murray, 2013). It is an indicative species of upper and high marsh above MHW, preferably in marine-influenced areas (De Rijk, 1995a; De Rijk and Troelstra 1997). Therefore, it can be dominant at the transitional high marsh zone just below the MHW (Sen Gupta, 2002). The range of salinity tolerated in marginal marine southern Scandinavia is 20–28‰ (Alve and Murray, 1999). This species is better represented in transitional and high marsh zones of Portuguese NW coast of Minho and Lima estuaries (Fatela et al., 2007, 2014) than in the southwestern ones (authors unpublished data). Referred as rare in the living assemblages of Guadiana estuary (Camacho et al., 2015).

***Trochammina inflata* (Montagu, 1808); Plate II, figs 1a–c**

1808 *Nautilus inflatus* Montagu, p. 81, pl. 18, fig. 3.

2006 *Trochammina inflata* (Montagu, 1808) – Horton and Edwards, p. 69, pl. 2, figs 8a–d.

**General ecology:** This is the typical mid marsh species, widely distributed throughout the Atlantic and Pacific oceans including the marginal marine settings (Murray, 2006, 2013). It is common to abundant above MHW in New Zealand salt marshes and frequently, comprises >80% of faunas at about MHWS (Hayward et al., 1999). Its distribution of maximum abundance suggests more tolerance to lower salinity than *J. macrescens* in brackish-water environments (Hayward et al., 1999). *Trochammina inflata* can be codominant with *J. macrescens* in the living and dead assemblages, however in the Portuguese southwestern marshes it tends to be less abundant when they occur together (Fatela et al., 2009b; authors unpublished data). This species is absent at the high marsh of the Minho estuary during periods of high average annual precipitation, but it became significant, after a set of consecutive dry years that lead to the sediment interstitial salinity rise (Fatela et al., 2014).

***Trochamminita salsa* (Cushman and Brönnimann, 1948); Plate I, fig. 1a–c**

1948b *Labrospira salsa* Cushman and Brönnimann, p.16, p 1.3, figs. 5–6.

1957 *Alveophragmium salsum* (Cushman and Brönnimann) – Todd and Brönnimann, p. 23, pl. 2, fig. 3.

1957 *Trochamminita salsa* (Cushman and Brönnimann) – Saunders 1957, p. 6, pl. 1, figs 3–8.

1999 *Trochamminita salsa* (Cushman and Brönnimann) – Hayward et al., p. 217, pl. 1, figs 30–32.

1948b *Trochamminita irregularis* Cushman and Brönnimann, p. 17, pl. 4, fig. 1–3.

1957 *Trochamminita irregularis* Cushman and Brönnimann – Saunders, p. 4, pl. 2, figs 3–8.

1957 *Trochamminita irregularis* Cushman and Brönnimann – Todd and Brönnimann, p. 30, pl. 4, figs. 19–22.

**General ecology:** This species is abundant in the New Zealand brackish upper reaches of estuaries and in the mouth of small streams towards the limits of salt water intrusion. It is more abundant in the inter tidal lower salinity environments, but may also live subtidally (Hayward et al., 1999). It is considered by Hayward (2014) as the foraminiferal species most tolerant to low salinity (~5–20‰) and to the highest tidal settings. Sometimes comprises >80% of the foraminiferal faunas in the uppermost reaches of estuaries (Hayward et al., 1999). In a scale of preference for increasing salinity, *T. salsa* represents the least saline end member. Concerning the tidal exposure, the *Trochamminita* association ranges between MSL and extreme high water spring – EHWS (Hayward et al., 1999; Sen Gupta, 2002). Near monospecific assemblages have been recorded at the marsh-to-upland transition, close to MHHW, where *J. macrescens* is the species more commonly found (e.g., Scott and Medioli, 1978; Scott and Medioli, 1980; Gehrels, 1994; Horton and Culver, 2008). Although, *T. salsa* seems to substitute *J. macrescens*, *T. inflata* or *Miliammina obliqua* dominated-faunas under lower salinity conditions at this tidal high levels, often where freshwater seepage is significant (Hayward et al., 2010; Hayward, 2014). *Trochamminita salsa* is present under low salinity conditions in the Caminha high marsh dead assemblages (lower Minho estuary), associated with *H. manilaensis*, *H. wilberti* and *P. limnetis* (Fatela et al., 2014). It is also present (living and dead) at mid estuarine marshes, as accessory species, from mud flat to high marsh in Tejo, Sado and Mira estuaries. Even though, it is most

significantly associated with *J. macrescens* above highest high tide level in Mira, where it reaches 11% of dead assemblage and 23% of living assemblage (authors unpublished data).

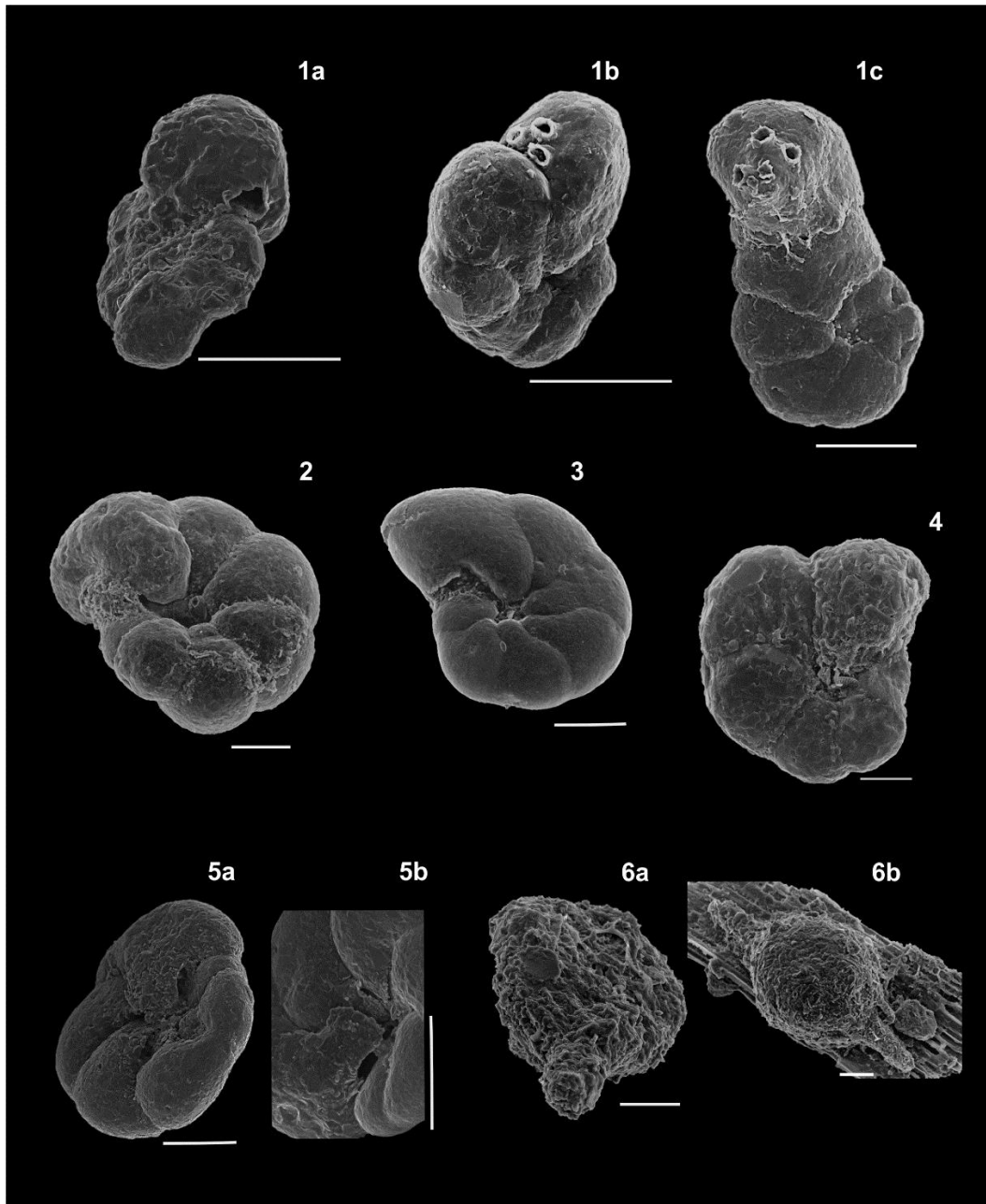


### References (appendix 3)

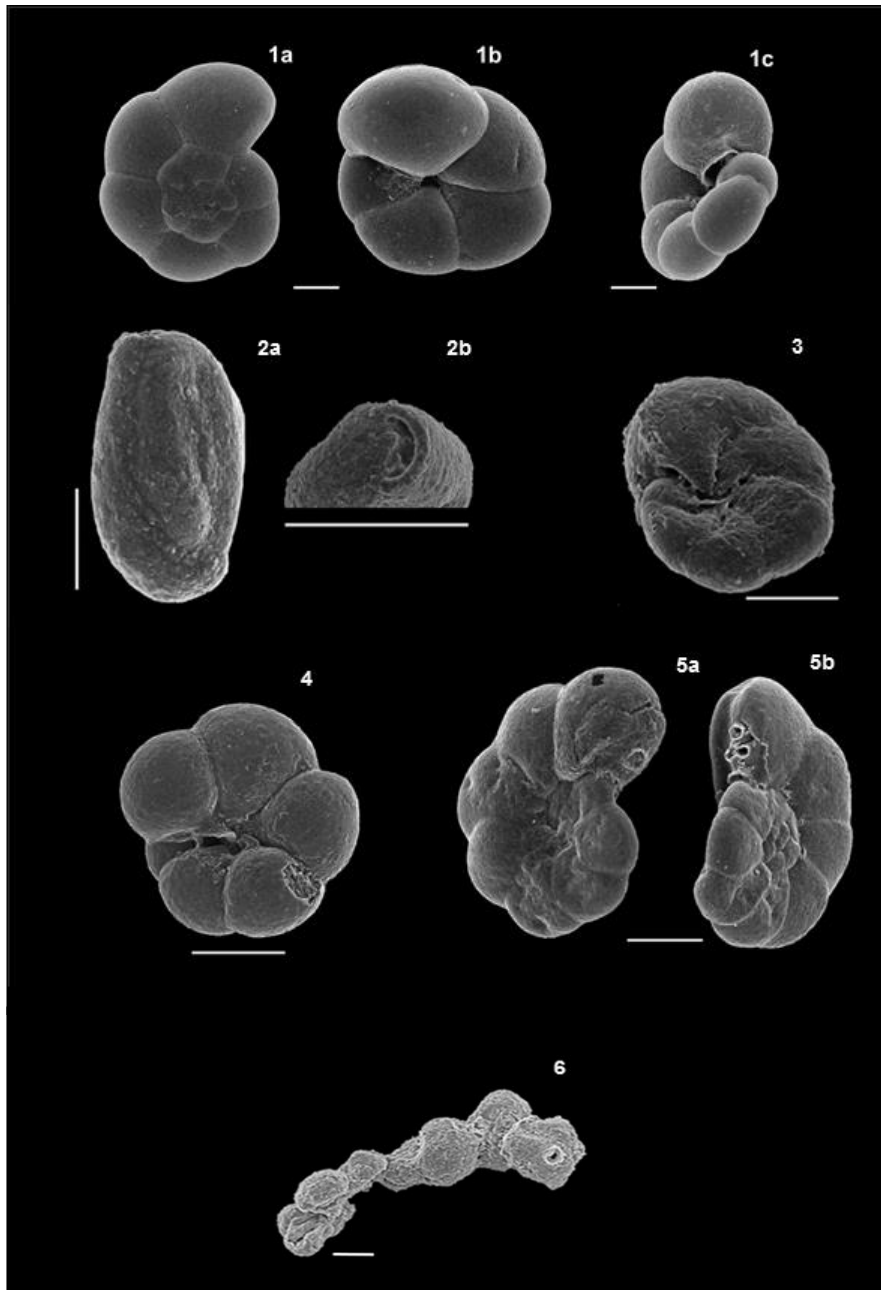
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**Plate I.** Scale bar 100  $\mu\text{m}$ . **1a** – *Trochamminita salsa* (Cushman and Brönnimann, 1948), with a single aperture in the last chamber; **1b,c** – *T. salsa* irregular forms with backward secondary apertures in the last chamber; **2** – *Haplophragmoides manilaensis* Andersen, 1953; **3** – *Haplophragmoides wilberti* Andersen, 1953; **4** – *Haplophragmoides* sp.; **5a** – *Tiphotrocha comprimata* (Cushman and Brönnimann, 1948), ventral face and oral view; **5b** – *T. comprimata*, detail of secondary apertures; **6a** – *Pseudothurammina limnetis* (Scott and Medioli, 1980), apertural view of a free specimen; **6b** – *P. limnetis* sessile specimen attached to a marsh plant debris.



**Plate II.** Scale bar 100  $\mu\text{m}$ . **1a** – *Trochammina inflata* (Montagu, 1808), dorsal face; **1b** – *T. inflata*, ventral face; **1c** – *T. inflata*, apertural view; **2a** – *Milliammina fusca* (Brady, 1870); **2b** – *M. fusca*, apertural view; **3** – *Paratrochammina guaratibaensis* Brönnimann, 1986, ventral face; **4** – *Siphotrochammina lobata* Saunders, 1957, ventral face; **5a** – *Jadammina macrescens* (Brady, 1870), ventral face; **5b** – *J. macrescens*, dorsal view; **6** – *Polysaccammina ipohalina* Scott, 1976. Scale bar 50  $\mu\text{m}$  for plate figure 6.