

Marine *Mastogloia* Thwaites ex W. Sm. species (Bacillariophyceae) from a North-Eastern Atlantic island

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Résumé – Espèces marines du genre *Mastogloia* Thwaites ex W. Sm. (Bacillariophyceae) d'une île de l'Océan Atlantique Nord-Est. Cinquante-huit espèces appartenant au genre *Mastogloia* ont été répertoriées dans des prélèvements effectués dans la zone infralittorale (-1,5 à - 7 mètres sous le zéro des cartes) sur la côte d'une île située au Nord-Est de l'Océan Atlantique (Île de Groix). La majorité de ces espèces est présente dans les régions tropicales et subtropicales. Cette étude apporte de nouvelles informations sur la distribution géographique de ces espèces. En outre, la morphologie de quatre espèces non identifiées est décrite en microscopie photonique.

Mastogloia/ Atlantique Nord-Est / Bretagne / région d'eau froide / zone infralittorale

Abstract – Fifty eight *Mastogloia* species were found in samples collected in the sublittoral zone (1.5 - 7 m charted depth) on the coast of a North-Eastern Atlantic island (Groix Island). Most of them are usually present in tropical and subtropical waters. The objective of this study was to provide new information on the biogeography of the genus *Mastogloia*. In addition, the morphology of four undetermined taxa was described using LM.

Mastogloia/ North-Eastern Atlantic/ Brittany/ cold-water region/ sublittoral zone.

INTRODUCTION

The raphid *Mastogloia* Thwaites ex W. Smith is predominantly a marine genus in the division Bacillariophyta (Round *et al.*, 1990). It is one of the largest diatom genera (more than 400 published taxa, Novarino, 1989). It should be a modern one, still undergoing rapid evolution and, likely, the full extent of this genus has not yet been mapped (Paddock & Kemp, 1990). This genus has naviculoid valves which are usually isopolar. Its diagnostic character is the presence of the partectal ring which represent a modification of the valvocopula (Paddock & Kemp, 1990). The partectal ring bears a number of hollow chambers, the partecta, which may be regular or variable in shape and size. The arrangement of this feature can be clearly observed in the LM and provides, with the striation of the valves, a practical way of describing the differences between most species.

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The genus has a tropical and subtropical worldwide distribution (Hustedt, 1931-1959; Voigt, 1942, 1952, 1955; Ricard, 1973; Yohn & Gibson, 1981, 1982; Witkowski *et al.*, 2000; Hein *et al.*, 2008; Pennesi *et al.*, 2011; Pennesi *et al.*, 2012, Pennesi *et al.*, 2013; Lobban *et al.*, 2012; Lobban & Pennesi, 2014). It is also present in temperate regions (Zanon, 1947, 1948; Voigt, 1963; Thomas, 1982), but is poorly represented in cold-water environments (Auby, 1993; Barber *et al.*, 1996). It is usually the most prominent and abundant epipellic or epiphytic representative in a biofilm community (Pennesi *et al.*, 2011; Loir & Novarino, 2013).

Recently, a sixty of *Mastogloia* species was found in samples collected around the Groix Island between 1.5 and 4.5 m depth and at 6-7 m depth. The purpose of this paper is to provide a contribution to the knowledge of the biogeography of the genus *Mastogloia* by pointing out that a significant number of *Mastogloia* taxa occur further north than previously known.

MATERIALS AND METHODS

Groix is a French island in South Brittany, at about 5 km from the continental coast (Fig. 1). The temperature of the sea water varies, according to the year, between 16 and 19.5°C during the summer and between 8.5 and 10°C during the winter. The salinity is rather stable, varying between 33 and 35 psu (data from Météo France-PREVIMER).

Samples of sandy sediments were collected during periods of calm at the three following sites (Fig. 1), situated in the sublittoral zone

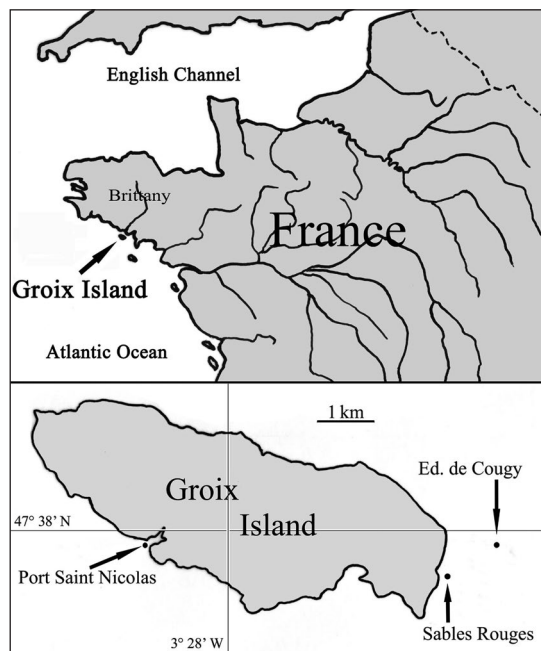


Fig. 1. Maps showing the localisation of the Groix Island, and the sampling areas around this island.

at the three following sites (Fig. 1), situated in the sublittoral zone (Lewis 1964). Site A: at the “Sables Rouges” (3° 25’ 02.1” W, 47° 37’ 39.3” N). Site B: at “Port Saint Nicolas” (3° 29’ 11.0” W, 47° 37’ 55.6” N). Site C: near the wreck “Edouard de Cougy” (3° 24’ 10.0” W, 47° 37’ 53.4” N). Samples were collected twice or three times during the summer, by snorkelling at the sites A and B and by scuba diving at the site C. At the site A, they were collected in 2014 at 1.5-2 m depth (depths are charted depths). At the site B, they were collected in 2013 and in 2014 between 1.5 and 4.5 m depth. At the site C, samples were collected from 2004 to 2011 at 6-7 m depth. Sixty one samples were also collected by scuba diving, from 2004 to 2011, around the Groix Island, between 10 and 23 m depth.

Each sample was collected by scraping away the top 3-5 mm of sandy sediment with a 50-ml Falcon tube at two or three adjacent places. After diluting 50:50 with seawater, the sample was vigorously shaken, then allowed to rest briefly to allow settlement of mineral and large particles. The supernatant was collected and allowed to rest for 24 hours. The obtained pellet was suspended in 3 ml seawater with 4% neutral formaldehyde. Frustules/valves were cleaned using hydrogen peroxide and/or sodium hypochlorite, then mounted in Melmount™ (ND = 1.704; Cargill Labs., Cedar Grove, N.J., USA). They were observed and photographed using an Olympus CH40 microscope.

Most of the observed *Mastogloia* taxa are very rare in the samples. A total of 12 slides was carefully scanned for the whole samples collected on the sites A and B and a total of 10 slides for the samples collected on the site C. On each slide around 1 to 3 thousands of total frustules/valves were present (extrapolation of data obtained on small slide areas). So, no quantitative study was performed and the numbers of frustules/valves indicated in the table 1 just provide an indication of the relative presence of the various observed taxa in the sites A+B and C

Frustule/valve measurements and striae counts were carried out on numerical micrographs at magnifications equal or higher to x3500. Valve outlines are described according to Hendey (1964) and the terminology for the morphological features is that proposed by Paddock & Kemp (1990).

RESULTS

On the three sites, a total of fifty eight *Mastogloia* taxa was observed (Table 1). Fifty two were present on the sites A+B and six on the site C. Four taxa were predominantly present on the sites A+B: *Mastogloia corsicana* Grunow in Cleve & Möller, *M. decipiens* Hustedt, *M. decussata* Grunow and *M. erythraea* Grunow. The two species *Mastogloia elegans* Lewis and *Mastogloia* sp. P were the more frequent ones on the site C during the summers 2004 and 2005. They were not found on the sites A and B. From 2006 to 2011, none *Mastogloia* species was observed in the samples collected on the site C. Only 8 valves of *Mastogloia* taxa were found in the sixty one samples collected between 10 and 23 m depth around the Groix Island.

The *Mastogloia* species

Fifty one of the found species are named species (Table 1) which were identified as their morphological features and biometric data conform to those indicated in the original and in the new diagnoses. Nevertheless, 2 taxa display most of the characters indicated in the diagnoses except one. So their identification remains doubtful. Our specimen of *Mastogloia gracilis* (?) display 9-9.5 partecta in 10 µm instead of 7 and in our specimen of *Mastogloia laterostrata* (?) the 2 longitudinal ribs enclosing the raphe are rather light than dense. As observed in the French Lesser Antilles (Loir & Novarino, 2013), valves/frustules which conform to most of the diagnostic characters of *Mastogloia erythraea* (Hustedt, 1931-1959), display high variations of their shape and size. The three forms f1, f2 and f3 described by Loir & Novarino (2013) are present at the Groix Island. These three forms of *Mastogloia erythraea* represent likely a complex of related offsprings in need of

Table 1. Presence of *Mastogloia* species in the investigated sites at the Groix Island (numbers of observed valves/frustules). Reported presence on the European Atlantic coasts and on the coasts of the Mediterranean Sea and related seas. A: Auby 1993. B: Barber et al, 1996. C: Germain, 1981. D: Gaj-Levra, 1927. E: Hustedt, 1931-1959. F: Hendey, 1954. G: Marchesoni, 1954. H: Peragallo & Peragallo, 1897-1908. J: Rampi, 1940. K: Rampi, 1942. L: Tomas, 1982. M : Vilicic et al., 2002. N : Witkowsky et al., 2000. P: Zanon, 1940. Q: Zanon, 1947. R: Zanon, 1948. S: Sabanci, 2013. T: Simonsen, 1962. Corf., Crete, Dalm., Gree., Sard.: Loir 2010-2014; Corfou, Crete, Dalmatia, Greece and Sardinia.

	Sites A, B 2013-2014 1.5-4.5 m	Site C 2004-2005 6-7 m	N-E Atlantic Ocean	Mediterranean Sea and related seas
<i>Mastogloia acutiuscula</i> Grunow in Cleve	1			E, P, Q, R
<i>Mastogloia acutiuscula</i> var. <i>elliptica</i> Hustedt	1			Crete Dalm. Sard.
<i>Mastogloia angulata</i> Lewis	1			D, J, L, M, P, Q
<i>Mastogloia angusta</i> Hustedt	1			Q
<i>Mastogloia apiculata</i> W. Smith	1		T	M, P, Q, R
<i>Mastogloia asperula</i> Grunow	2			E
<i>Mastogloia asperuloides</i> Hustedt	3			Crete Dalm. Gree.
<i>Mastogloia binotata</i> (Grunow) Cleve	2		B, H, F	E, M, P, Q, R, S
<i>Mastogloia biocellata</i> (Gr.) Novarino & Muftah	1			Crete Dalm. Sard
<i>Mastogloia corsicana</i> Grunow	22			E, J, M, P, Q, R
<i>Mastogloia crucicula</i> (Grunow) Cleve	4		N	J, K, L, M, P, Q
<i>Mastogloia crucicula</i> var. <i>alternans</i> Zanon	2			Sard.
<i>Mastogloia cuneata</i> (Meister) Simonsen	4			N
<i>Mastogloia cyclops</i> Voigt	3			
<i>Mastogloia decipiens</i> Hustedt	18			E, P
<i>Mastogloia decussata</i> Grunow	16			Corf. Crete Gree.
<i>Mastogloia elegans</i> Lewis		10		E
<i>Mastogloia elliptica</i> (Agardh) Cleve		3	E, C, F	E
<i>Mastogloia erythraea</i> Grunow f. 1	8			? J, M, P, Q, R
<i>Mastogloia erythraea</i> Grunow f. 2	5			? J, M, P, Q, R
<i>Mastogloia erythraea</i> Grunow f. 3	8			? J, M, P, Q, R
<i>Mastogloia erythraea</i> var. <i>biocellata</i> Grunow	3			H
<i>Mastogloia exigua</i> Lewis	1		A, H	
<i>Mastogloia exilis</i> Hustedt	1			Q
<i>Mastogloia fimbriata</i> (Brightwell) Cleve	2		N	M
<i>Mastogloia foliolum</i> Brun	2			Corf. Gree. Sard.
<i>Mastogloia gilberti</i> A. Schmidt	1	1	H	E
<i>Mastogloia graciloides</i> Hustedt	3			Gree. Sard.
<i>Mastogloia grunowii</i> A Schmidt	7			E, Q, R, S
<i>Mastogloia horvathiana</i> Grunow	1			E
<i>Mastogloia hustedtii</i> Meister	1			
<i>Mastogloia ignorata</i> Hustedt	7			E, L, S

	Sites A, B 2013-2014 1.5-4.5 m	Site C 2004-2005 6-7 m	N-E Atlantic Ocean	Mediterranean Sea and related seas
<i>Mastogloia labuensis</i> var. <i>lanceolata</i> Hustedt	4			Corf. Crete Dalm.
<i>Mastogloia laminaris</i> Grunow	1			E, Dalm.
<i>Mastogloia macdonaldii</i> Greville	2			D, E, M, R
<i>Mastogloia mauritiana</i> Brun	3			E, M, P
<i>Mastogloia ovalis</i> A. Schmidt	1		N	E
<i>Mastogloia ovata</i> Grunow	3		B, F	E, G, H, J, M, P, R
<i>Mastogloia ovulum</i> Hustedt	2		N, F	E, M, P, Q
<i>Mastogloia pisciculus</i> Cleve	3		A	L
<i>Mastogloia pseudoexigua</i> Cholnoky	1		B	
<i>Mastogloia pulchella</i> Cleve	1			R
<i>Mastogloia punctifera</i> Brun	3			E, M
<i>Mastogloia pusilla</i> Grunow	6		A, H	D, L, M, Q, R
<i>Mastogloia robusta</i> Hustedt	3			L
<i>Mastogloia similis</i> Hustedt	6			Corf. Dalm. Gree.
<i>Mastogloia subaffirmata</i> Hustedt	14			E, P, R
<i>Mastogloia subaspera</i> Hustedt	3			E, M, Corf. Gree.
<i>Mastogloia vasta</i> Hustedt	2			S, Crete Dalm. Sard.
<i>Mastogloia gracilis</i> Hustedt?	1			
<i>Mastogloia laterostrata</i> Hustedt?	4			
<i>Mastogloia</i> sp. 4	1			
<i>Mastogloia</i> sp. 8		1		
<i>Mastogloia</i> sp. 9	2			
<i>Mastogloia</i> sp. C		7		
<i>Mastogloia</i> sp. F	2			
<i>Mastogloia</i> sp. P		25		
<i>Mastogloia</i> sp. W	2			

taxonomic revision. The longitudinal ridges bordering the raphe (“gutter”, Paddock & Kemp, 1990), characteristic of *Mastogloia erythraea* Grunow (Stephens & Gibson, 1980; Novarino & Muftah, 1991) are visible only on the fl valves

Seven taxa are undetermined. Three of them – *Mastogloia* sp. 4, *M.* sp. 8 and *M.* sp. 9 – are identical to the three undetermined taxa present in the French Lesser Antilles which have been described by Loir & Novarino (2013). The 4 other undetermined taxa are described below.

Description of four undetermined *Mastogloia* species

Mastogloia sp. C (Fig. 2). Valves linear-lanceolate with rostrate-capitate apices, 17-23 µm long, 4-5 µm broad. Raphe barely sinuous. Axial area very narrow. Central area small, circular. Transapical striae parallel to slightly radiate towards the apices,

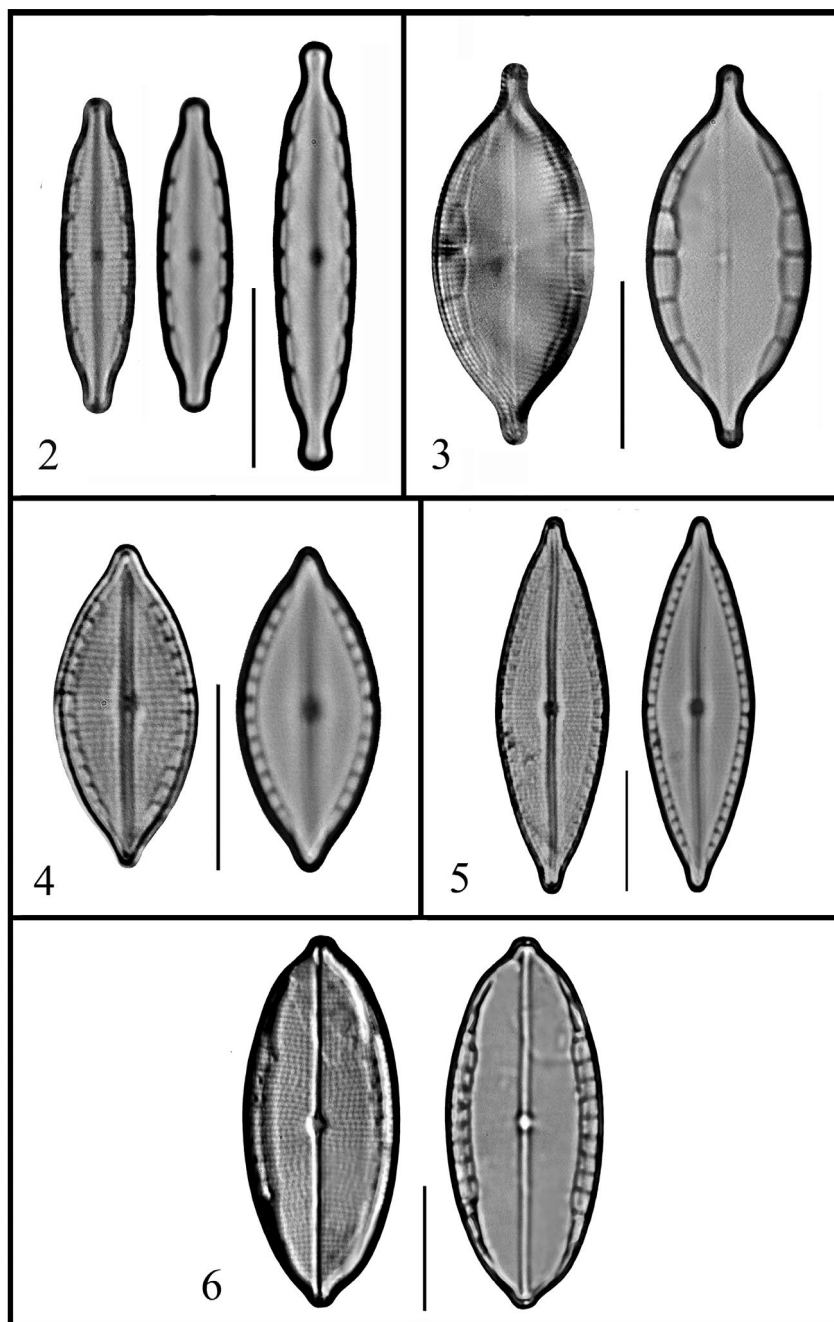


Fig. 2-6. **2.** *Mastogloia* sp. C, two valves, the short one in two different LM focal views. Scale bar = 10 μm . **3.** *Mastogloia* sp. F, one valve in two different LM focal views. Scale bar = 10 μm . **4-5.** *Mastogloia* sp. P, two valves, each in two different LM focal views. Scale bar = 10 μm . **6.** *Mastogloia* sp. W, one valve in two different LM focal views. Scale bar = 10 μm .

25-28 in 10 μm . Partecta equal, rectangular apically elongated, 4-5.5 in 10 μm , 0.3-0.6 wide, extending below the apices. Inner margins flat or slightly convex.

Mastogloia sp. F (Fig. 3). Valves lanceolate with rostrate apices, 23-25 μm long, 9-10 μm broad. Raphe linear. Axial area very narrow. Central area small circular. Transapical striae barely radiate in the middle becoming very radiate towards the apices, 29-32 in 10 μm . Partecta rectangular apically elongated, subequal, extending to a short distance of the apices. A central group of 2 or 3 partecta, 2.7-4.2 in 10 μm , 1.5-1.6 μm wide. Other partecta smaller, 4-4.7 in 10 μm , 1-1.1 μm wide. Inner margins convex. This species has some characters in common with *Mastogloia foliolum* Brun in A. Schmidt. However, the numbers of large partecta (2.7-4 vs 4-5) and of small partecta (4-4.7 vs 6-9) in 10 μm point out that they should be two different species.

Mastogloia sp. P (Figs 4, 5). Valves lanceolate with cuneate apices, 17-34 μm long, 7-9 μm broad. Raphe straight. Axial area very narrow. Central area small, circular. Transapical striae parallel to slightly radiate towards the apices, 25-27 in 10 μm , crossed by sinuous longitudinal lines, 25 in 10 μm . Partecta equal, approximately square, extending up to the apices, 8-10 in 10 μm , 0.6-1.2 μm wide. Inner margins flat to barely convex. At first sight, this species resembles to *Mastogloia tenera* Hustedt. It differs from this species by the striation of the valves (transapical striae crossed by oblique striae in *M. tenera*) and by a higher number of partecta in 10 μm (5-8 in *M. tenera*).

Mastogloia sp. W (Fig. 6). Valves elliptical with subrostrate apices, 30-34 μm long, 13-15 μm broad. Raphe straight, external central endings proximate. Axial area narrow, central area small, circular. Transapical striae weakly radiate, 19-22 in 10 μm , crossed by longitudinal wavy ribs, 18 in 10 μm . A central group of 8 to 11 partecta equal, approximately square, 6-7 in 10 μm , 1.5-1.8 μm wide, distributed along 42-48% of each valve side. Inner margins flat or barely convex. The two specimen have some characters in common with *Mastogloia smithii* Thwaites (Hustedt 1931-1959, Witkowski et al. 2000): size of the valves, number of transapical striae and organization of the partectal ring. However, the shape of the valves and that of the central area differ from those of *Mastogloia smithii* and axial costae are lacking (Lee et al., 2014).

DISCUSSION

Most of the forty nine named *Mastogloia* taxa from the Groix Island are usually present in tropical and subtropical regions (Hustedt 1931-1959; Hein et al., 2008; Loir & Novarino, 2013; Paulmier, 1993; Yousif Al-Yamani & Saburova, 2011; Witkowski et al., 2000) and in the Mediterranean Sea (Table 1). Only a dozen have been found previously, more or less occasionally, on the European Atlantic coasts (Table 1).

It could seem surprising to find a population of such *Mastogloia* species in the cold-temperate waters of the South Brittany coast. At our knowledge, the studies which mention the presence of *Mastogloia* species on the European Atlantic coasts have been carried out on sediments or seaweeds or sea-grass leaves, collected in the eulittoral zone (Auby, 1993; Barber et al., 1996). No investigation was carried out on the microphytobenthos from the sublittoral zone. As Round et al. (1990) have written, "The benthic diatom communities are far more difficult to sample... than the plankton and so they have been largely ignored by ecologists". Our study points out that a lot of *Mastogloia* species could be present, elsewhere on the European

Atlantic coasts, in the first meters of the sublittoral zone. The low representation of the *Mastogloia* genus in the collected samples suggests that the South Brittany coast represent the northern limit of the geographical distribution of most of the observed *Mastogloia* species.

Between 1.5 and 4.5 m depth fifty two species were observed. Only six different species were found at 6-7 m depth. Between 10 and 23 m depth, very scarce *Mastogloia* valves/frustules were found. Although not sustained by quantitative data, these observations ask the question of the factors which control the distribution of the *Mastogloia* species, in the sublittoral zone, as a function of the depth. The light and the temperature could play a decisive role.

Seven *Mastogloia* species found around the Groix Island are undetermined. It may not be excluded that some of them were already described.

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