Kraberg et al. Marine Biodiversity Records (2018) 11:21
https://doi.org/10.1186/s41200-018-0155-0

Marine Biodiversity Records

MARINE RECORD Open Access

Further records of a new diatom species in the English Channel and North Sea: the importance of image-referenced data

Alexandra C. Kraberg[1*], Claire E. Widdicombe[2], Rachel Beckett[3], Johannes Rick[4], Paul Rooks[2] and René van Wezel[5]

Abstract

Background: In September 2015, an at the time undescribed, autotrophic taxon was discovered in the western English Channel (station L4) and also in the eastern English Channel and Celtic Sea during the Polarstern Cruise PS95 a month later. Subsequent investigations revealed further extensive records (going back to 1992) at stations in the English Channel and the southern North Sea (e.g. Helgoland Roads and Sylt Roads time series stations). Stations in the Northern North Sea have not recorded this distinct taxon. With the available records and crucially, the accompanying image metadata, we are able to chart a clear distribution record with occurrences being restricted to the southern North Sea and English Channel.

Methods: The biological data shown are from Lugol-fixed Utermöhl counts and investigations of live and Formalin-fixed net hauls (20 μm mesh size). All image material shown is available in the online repository Planktonnet (http://planktonnet.awi.de).

Results: We report the distribution, based on geo-referenced image records of an easily recognisable, yet taxonomically uncertain, autotrophic organism.

Conclusions: Distribution patterns of the unidentified autotrophic taxon suggests entry of this taxon into/out of the North Sea via the English Channel. Further investigations providing image-documented information over several years is clearly necessary to clarify its dynamics and ecological characteristics.

Keywords: Diatom, English Channel, North Sea, Phytoplankton

Background

Regular phytoplankton monitoring stations in the North Sea and English Channel possess detailed records of the taxa that have been observed there for at least 20 years (Hoppenrath 2004; Widdicombe et al. 2010). These include the Western Channel Observatory's stations L4 and E1, stations along the Dutch coast, the Biologische Anstalt Helgoland with its Helgoland Roads long-term phytoplankton time series (located in the German Bight (Wiltshire et al. 2010)) as well as the Wadden Sea station Sylt. Collectively, these time series stations are ideally placed to chart differences in the dynamics and distribution of phytoplankton diversity in the English Channel and North Sea. However, while the taxon lists generated during routine regular observations are extensive, they often comprise a large number of unidentified taxonomic units which are only recorded as size classes or verbatim taxa without assigning an accepted species name to the taxon (as an example the Helgoland Roads taxon list comprises 356 taxa and 250 distinct species). The comparability of the unidentified taxa between different time series stations is usually very limited, especially size classes e.g. unidentified Gymnodiniaceae, can also comprise different species at different times of the year. Increasingly this situation is remedied however by the fact that analysts produce detailed photographic documentation of the taxa (both unidentified and known tax) that are routinely recorded or appear at a site for the first time. Here we report a first distribution record, collated from multiple time series stations and cruises of

* Correspondence: Alexandra.Kraberg@awi.de
[1]Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Biologische Anstalt Helgoland, Kurpromenade 201, 27498 Helgoland, Germany
Full list of author information is available at the end of the article

an organism for which the taxonomic identity is still under discussion but that can be identified reliably on the basis of its morphological characteristics based on photographic material available in a number of research stations.

This organism (referred to as the 'pringle') is morphologically distinct, with an undulating parabeloid movement that appears to be typical for this organism. It can be identified reliably and data for this taxon can be analysed jointly between different data sets. Here we review all available data for this taxon to make a first attempt at characterizing it ecologically.

Methods

For this study, records from a large number of ship records and time series stations were collated from live and preserved samples. For counts in the context of routine monitoring programmes, Lugol's-fixed sample counts are used by each time series represented here. Additional records were obtained from net hauls (20 μm mesh size) and analysed live (L4 and E1, Sylt Roads) or fixed in hexamine-buffered Formalin (Helgoland Roads). Pre-requisite for being included in the study was that at least some records were annotated photographically, as there is no consistently assigned taxonomic name for this taxon yet. Image material obtained for this study was from both Lugol's-fixed and live material: The characteristics of this distinctive taxon as described below, meant that this diverse material was still usable for documenting the presence of this taxon. All photographic material was taken at a magnification of × 200 and different camera set ups including e.g. Zeiss Axiocam Hrc (Helgoland Roads) and a Leica DFC-450C and Olympus DP25 at L4 and E1). All material used for this study has been archived online in the planktonnet database (http://planktonnet.awi.de//index.php?thematicid=2086). The map of species distribution spread was generated using QGIS 3 (QGIS Development Team 2018, https://qgis.org/en/site/).

Results

Distribution data

The earliest record documented by image material was from a cruise in the English Channel in 1992, where live material was taken by the Dutch monitoring agency within the framework of research on Harmful algal blooms (HAB) (Rademaker and Koeman 1992). The cells were provisionally identified as *Campylodiscus*, and their typical movement was noted. In 2001, the taxon was spotted again on the monitoring stations along the Dutch coast, and since then, routinely monitored within the Dutch monitoring network (Veen et al. 2015).

In the following years particularly after 2012 this unclassified taxon has been reported by a number of time series stations in the English Channel, southern North Sea and the Dutch Wadden Sea. In September 2015 it was observed at Station L4 in the western English Channel as well as on Polarstern Cruise PS95 (in October and November 2015) at station PS095–001 in the eastern English Channel and PS95–002 in the Celtic Sea. The latter was the only record outside the North Sea or English Channel. (Fig. 1, Table 1). In July 2016 it was also detected at a site near the mouth of the River Elbe (Station Elbe 6 of the Helgoland transect surveys). Further records have since been confirmed from Helgoland Roads and other coastal stations in the German Bight (data for 2017 and 2018 not shown).

Earlier anecdotal reports also exist for Helgoland and the Waddensea Station Sylt in northern Germany. However, as these were not documented in sufficient detail (e.g. with image material) they have not been included in the present communication. To our knowledge, this distinctive taxon has not yet been found in the Northern North Sea (e.g. the Scottish Coastal Observatory), Central North Sea or the Baltic (E. Bresnan and M. Johansen pers. comm).

Taxon description

Cells appear variable in symmetry (depending on the orientation of the cell) from oval to wedge-shaped or undulating. They are also clearly pigmented. The nucleus is round and located centrally within the cell. Cells contain several large plate-like chloroplasts, often showing typical squarish inclusion bodies. Cells are motile, with undulating movements and rotation along their long axis. Movement is slow and a flagellum has not been observed. Single or paired cells can occur 'naked' or within what appears to be a mucous envelope. The enveloped stage is also motile, moving inside the mucous envelopes. Particularly the enveloped forms can easily be discerned from photographs and in different fixation methods (compare for instance Fig. 2a (live) and g or h which are Lugol's fixed).

Taxon identity

The identity of the organism requires clarification. Although clearly motile, flagella have never been observed in cells of any of our samples and the taxon has therefore been referred to as a diatom. Cleaned specimen seem to confirm this view. A genus with a similar paraboloid symmetry is *Campylodiscus*, but this organism is generally much more heavily ornamented and most species are much larger than the taxon investigated here. Moreover, *Campylodiscus* is also often considered as a freshwater species (although it can also be found in coastal waters). Upon recording this species for the first time in samples from Dutch monitoring stations in the Southern North Sea, Lugol's-preserved cells were critically examined using oil immersion microscopy. Fine striation was observed on the surface of the cell, and a central nodule with reinforced structures appearing to

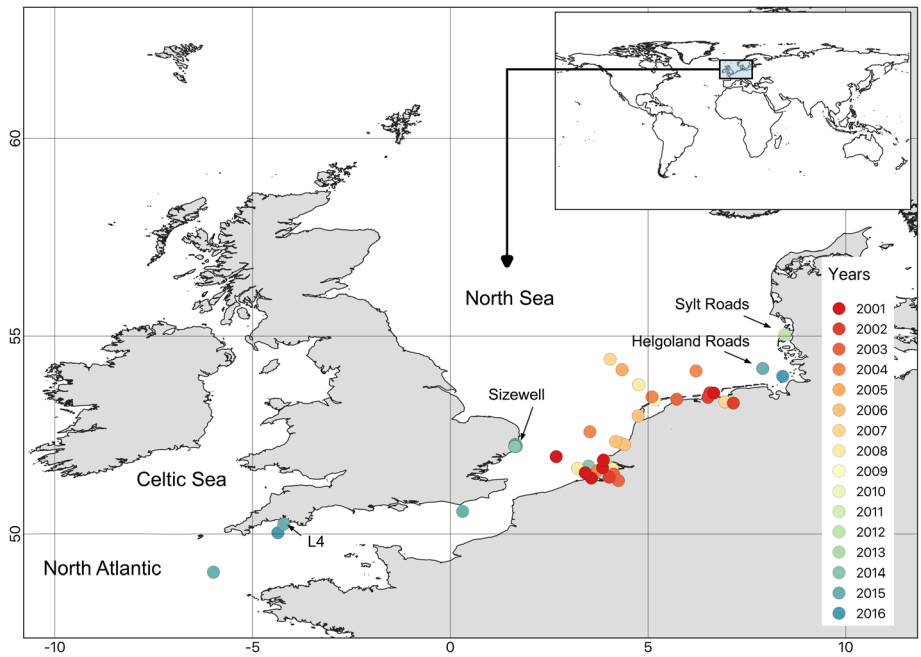

Fig. 1 Map of observational records of the unknown taxon named colloquially 'the pringle', due to its morphology. The occurrence records are colour-coded to show the years in which the organism was observed. Data up to 2016 were included

be striae is just discernible along the raphe (Fig. 3). Based on those characteristics, and due to the likeness to the drawing in Tomas (1997), this entity was therefore recorded as *Membraneis challengeri* (Grunow) Paddock in the Dutch data. The taxon has also been regarded similar to *Tropidoneis confusa* (=*Plagiolemma confusum*, (Hendey) Paddock) as described by Hendey, 1964.

However, the symmetry of the organism does not fit the description of either the symmetry of the basionym of *Membraneis challengeri*, *Navicula challengeri*, which is long and straight, nor the shape of *Tropidoneis confusa*. Finally, neither formal description mentions motility or the mucous envelopes in which cells are frequently found, both in live and preserved samples. During the submission process a new diatom species (*Plagiolemma distortum*) has been formally described that appears to fit the morphology of the taxon dealt with here (Nezan et al. 2018) and mentioned the mode of locomotion seen in our 'unidentified' organism. This type of locomotion appears to be non-typical for most other diatom species for which, a gliding motion along a substrate is more common. However, some diatoms also rotate during the process of forward motion (Cohn and Weitzell Jr. 1996; Edgar and Pickett-Heaps 1983).

Discussion

The identity of this taxon remains unclear. The entity has characteristics that link it to *Membraneis challengeri* but the motility, its symmetry and its mucous envelope are not found in descriptions of the above taxon, or any of its relatives within the Plagiotropidaceae such as *Ephemera* but fit with the newly described *Plagiolemma distortum* (Nezan et al. 2018).

In any case the cells are distinct enough to verify the occurrence of the taxon at a given station as long as good image records are also available so that a reliable distribution record can be assembled. The records collated for this study so far indicate a distribution that is restricted to the Southern North Sea and English Channel (based on 342 records) with occasional records from the Celtic Sea to the west of the English Channel. Through communication within the ICES expert group WGPME it was also confirmed that neither time series in the Baltic or the Coastal Scottish observatory have yet detected this species (M. Johansen, E. Bresnan pers. comm).

Considering only the years 2015 and 2016 (the best documented years in terms of the availability of image material) it would be tempting to consider this taxon as an Atlantic species that is advected into the North Sea only occasionally. For benthic neophytes reaching the island of Helgoland the English Channel was also suggested as an important immigration pathway by Franke and Gutow (2004) (see also: (Minchin et al. 2013)). In contrast, the earlier records would indicate a more coastal/brackish preference and therefore different direction of extending its range (see particularly data from the Dutch Delta and Wadden Sea, a site close to the Elbe estuary (Site Elbe 6 in Table 1)

Table 1 Table detailing occurrences and basic environmental factors at the time of occurrence

	Date	Station	Latitude	Longitude
2001	13.08.2001	VLISSGBISSVH	51.413	3.566
	14.09.2001	HUIBGOT	53.560	6.661
	24.09.2001	HAMMOT	51.676	3.849
	24.10.2001	GOERE6	51.870	3.872
	24.10.2001	WALCRN2	51.549	3.410
	24.10.2001	WALCRN70	51.957	2.678
	15.11.2001	WALCRN70	51.957	2.678
2002	05.07.2002	GROOTGND	53.305	7.157
	15.07.2002	ZUIDOLWOT	53.450	6.514
	16.07.2002	HANSWGL	51.437	4.014
	16.07.2002	ROTTMPT3	53.566	6.563
	16.07.2002	VLISSGBISSVH	51.413	3.566
	22.07.2002	HUIBGOT	53.560	6.661
	30.07.2002	VLISSGBISSVH	51.413	3.566
	01.08.2002	HAMMOT	51.676	3.849
	01.08.2002	ZUIDOLWOT	53.450	6.514
	02.08.2002	GROOTGND	53.305	7.157
	02.08.2002	HUIBGOT	53.560	6.661
	13.08.2002	ZUIDOLWOT	53.450	6.514
	14.08.2002	HANSWGL	51.437	4.014
	14.08.2002	VLISSGBISSVH	51.413	3.566
	02.09.2002	ZUIDOLWOT	53.450	6.514
	03.09.2002	HUIBGOT	53.560	6.661
	18.09.2002	HUIBGOT	53.560	6.661
	08.10.2002	HANSWGL	51.437	4.014
	18.11.2002	WALCRN70	51.957	2.678
2003	12.03.2003	DANTZGT	53.402	5.727
	14.03.2003	GROOTGND	53.305	7.157
	11.06.2003	LODSGT	51.516	4.127
	16.06.2003	HANSWGL	51.437	4.014
	10.07.2003	GROOTGND	53.305	7.157
	10.07.2003	HUIBGOT	53.560	6.661
	14.07.2003	VLISSGBISSVH	51.413	3.566
	03.10.2003	GROOTGND	53.305	7.157
	15.12.2003	SCHAARVODDL	51.351	4.251
2004	15.06.2004	WISSKKE	51.602	3.721
	06.07.2004	WISSKKE	51.602	3.721
	27.07.2004	HUIBGOT	53.560	6.661
	28.07.2004	HANSWGL	51.437	4.014
	03.08.2004	HAMMOT	51.676	3.849
	10.08.2004	HANSWGL	51.437	4.014
	25.08.2004	VLISSGBISSVH	51.413	3.566
	01.09.2004	HAMMOT	51.676	3.849
	01.09.2004	WISSKKE	51.602	3.721
	07.09.2004	HANSWGL	51.437	4.014
	07.09.2004	VLISSGBISSVH	51.413	3.566
	09.09.2004	HUIBGOT	53.560	6.661
	14.09.2004	HAMMOT	51.676	3.849
	22.09.2004	HANSWGL	51.437	4.014
	28.09.2004	HAMMOT	51.676	3.849
	28.09.2004	LODSGT	51.516	4.127
	28.09.2004	ROTTMPT70	54.118	6.213
	28.09.2004	WISSKKE	51.602	3.721
	29.09.2004	TERSLG10	53.461	5.100
	30.09.2004	WALCRN70	51.957	2.678
	07.10.2004	HANSWGL	51.437	4.014
	07.10.2004	VLISSGBISSVH	51.413	3.566
	12.10.2004	LODSGT	51.516	4.127
	12.10.2004	WISSKKE	51.602	3.721
	16.11.2004	NOORDWK70	52.586	3.530
2005	27.01.2005	TERSLG10	53.461	5.100
	16.08.2005	GROOTGND	53.305	7.157
	24.08.2005	HANSWGL	51.437	4.014
	27.10.2005	TERSLG100	54.150	4.341
	15.11.2005	WALCRN70	51.957	2.678
	22.11.2005	TERSLG100	54.150	4.341
	13.12.2005	WALCRN70	51.957	2.678
2006	05.07.2006	ZUIDOLWOT	53.450	6.514
	06.07.2006	HUIBGOT	53.560	6.661
	10.07.2006	VLISSGBISSVH	51.413	3.566
	20.07.2006	NOORDWK20	52.342	4.174
	26.07.2006	MARSDND	52.983	4.750
	17.08.2006	GROOTGND	53.305	7.157
	04.09.2006	VLISSGBISSVH	51.413	3.566
	18.09.2006	HUIBGOT	53.560	6.661
	20.09.2006	HANSWGL	51.437	4.014
	20.09.2006	VLISSGBISSVH	51.413	3.566
	26.09.2006	WISSKKE	51.602	3.721
	03.10.2006	HANSWGL	51.437	4.014
	03.10.2006	VLISSGBISSVH	51.413	3.566
	11.10.2006	NOORDWK2	52.261	4.405
	23.10.2006	LODSGT	51.516	4.127
2007	12.06.2007	BOCHTVWTM	53.3357	6.9439
	26.06.2007	HANSWGL	51.437	4.014
	27.06.2007	NOORDWK10	52.302	4.301
	11.07.2007	HANSWGL	51.437	4.014

Table 1 Table detailing occurrences and basic environmental factors at the time of occurrence *(Continued)*

	Date	Station	Latitude	Longitude
	11.07.2007	VLISSGBISSVH	51.413	3.566
	12.07.2007	BOCHTVWTM	53.3357	6.9439
	25.07.2007	GROOTGND	53.305	7.157
	25.07.2007	HUIBGOT	53.560	6.661
	14.08.2007	DANTZGT	53.402	5.727
	21.08.2007	ZUIDOLWOT	53.450	6.514
	22.08.2007	BOCHTVWTM	53.3357	6.9439
	27.08.2007	DANTZGT	53.402	5.727
	13.09.2007	WALCRN2	51.549	3.410
	19.09.2007	HANSWGL	51.437	4.014
	20.09.2007	ZUIDOLWOT	53.450	6.514
	26.09.2007	BOCHTVWTM	53.3357	6.9439
	02.10.2007	HANSWGL	51.437	4.014
	02.10.2007	VLISSGBISSVH	51.413	3.566
	16.10.2007	HANSWGL	51.437	4.014
	24.10.2007	TERSLG100	54.150	4.341
	24.10.2007	TERSLG135	54.416	4.040
2008	17.03.2008	GROOTGND	53.305	7.157
	07.07.2008	SCHAARVODDL	51.351	4.251
	09.07.2008	HANSWGL	51.437	4.014
	17.07.2008	WALCRN2	51.549	3.410
	17.07.2008	WALCRN20	51.659	3.219
	21.07.2008	VLISSGBISSVH	51.413	3.566
	28.07.2008	ZIJPE	51.646	4.097
	31.07.2008	DANTZGT	53.402	5.727
	01.08.2008	HUIBGOT	53.560	6.661
	05.08.2008	VLISSGBISSVH	51.413	3.566
	13.08.2008	HAMMOT	51.676	3.849
	13.08.2008	WISSKKE	51.602	3.721
	20.08.2008	NOORDWK10	52.302	4.301
	21.08.2008	GOERE2	51.8469	3.9155
	21.08.2008	GOERE6	51.870	3.872
	21.08.2008	WALCRN2	51.549	3.410
	27.08.2008	LODSGT	51.516	4.127
	29.08.2008	HUIBGOT	53.560	6.661
	01.09.2008	VLISSGBISSVH	51.413	3.566
	01.09.2008	ZUIDOLWOT	53.450	6.514
	09.09.2008	HAMMOT	51.676	3.849
	09.09.2008	LODSGT	51.516	4.127
	09.09.2008	WISSKKE	51.602	3.721
	15.09.2008	VLISSGBISSVH	51.413	3.566
	17.09.2008	TERSLG50	53.768	4.766
	17.09.2008	WALCRN2	51.549	3.410

Table 1 Table detailing occurrences and basic environmental factors at the time of occurrence *(Continued)*

	Date	Station	Latitude	Longitude
	28.09.2008	HUIBGOT	53.560	6.661
	13.10.2008	VLISSGBISSVH	51.413	3.566
	17.11.2008	WALCRN70	51.957	2.678
	10.12.2008	TERSLG100	54.150	4.341
	12.12.2008	WALCRN70	51.957	2.678
2009	02.06.2009	DANTZGT	53.402	5.727
	08.06.2009	HANSWGL	51.437	4.014
	23.06.2009	HANSWGL	51.437	4.014
	23.06.2009	VLISSGBISSVH	51.413	3.566
	02.07.2009	ZUIDOLWOT	53.450	6.514
	03.07.2009	GROOTGND	53.305	7.157
	06.07.2009	HANSWGL	51.437	4.014
	06.07.2009	VLISSGBISSVH	51.413	3.566
	17.07.2009	BOCHTVWTM	53.3357	6.9439
	17.07.2009	GROOTGND	53.305	7.157
	20.07.2009	HANSWGL	51.437	4.014
	03.08.2009	HANSWGL	51.437	4.014
	03.08.2009	VLISSGBISSVH	51.413	3.566
	17.08.2009	VLISSGBISSVH	51.413	3.566
	18.08.2009	BOCHTVWTM	53.3357	6.9439
	31.08.2009	HANSWGL	51.437	4.014
	31.08.2009	VLISSGBISSVH	51.413	3.566
	02.09.2009	ROTTMPT70	54.118	6.213
	15.09.2009	HANSWGL	51.437	4.014
	16.09.2009	WALCRN2	51.549	3.410
	22.09.2009	HAMMOT	51.676	3.849
	22.09.2009	WISSKKE	51.602	3.721
	23.09.2009	TERSLG10	53.461	5.100
	14.10.2009	HANSWGL	51.437	4.014
	14.10.2009	VLISSGBISSVH	51.413	3.566
	14.10.2009	WALCRN20	51.659	3.219
	15.10.2009	WALCRN70	51.957	2.678
	20.10.2009	HUIBGOT	53.560	6.661
	28.10.2009	TERSLG100	54.150	4.341
	09.11.2009	NOORDWK2	52.261	4.405
	10.11.2009	TERSLG100	54.150	4.341
	11.11.2009	NOORDWK10	52.302	4.301
	11.11.2009	WALCRN20	51.659	3.219
	11.11.2009	WALCRN70	51.957	2.678
	12.11.2009	GOERE6	51.870	3.872
	12.11.2009	WALCRN2	51.549	3.410
	17.11.2009	WISSKKE	51.602	3.721
	21.11.2009	MARSDND	52.983	4.750

Table 1 Table detailing occurrences and basic environmental factors at the time of occurrence *(Continued)*

	Date	Station	Latitude	Longitude
	07.12.2009	NOORDWK70	52.586	3.530
	08.12.2009	TERSLG10	53.461	5.100
	09.12.2009	GOERE6	51.870	3.872
	09.12.2009	WALCRN70	51.957	2.678
	17.12.2009	BOOMKDP	53.380	5.167
2010	15.01.2010	DANTZGT	53.402	5.727
	21.06.2010	HUIBGOT	53.560	6.661
	07.07.2010	BOCHTVWTM	53.3357	6.9439
	08.07.2010	HANSWGL	51.437	4.014
	13.07.2010	ROTTMPT3	53.566	6.563
	21.07.2010	HANSWGL	51.437	4.014
	21.07.2010	VLISSGBISSVH	51.413	3.566
	03.08.2010	GROOTGND	53.305	7.157
	18.08.2010	BOCHTVWTM	53.3357	6.9439
	18.08.2010	GROOTGND	53.305	7.157
	18.08.2010	HANSWGL	51.437	4.014
	18.08.2010	HUIBGOT	53.560	6.661
	18.08.2010	VLISSGBISSVH	51.413	3.566
	25.08.2010	WALCRN2	51.549	3.410
	02.09.2010	HANSWGL	51.437	4.014
	02.09.2010	VLISSGBISSVH	51.413	3.566
	06.09.2010	HUIBGOT	53.560	6.661
	15.09.2010	HANSWGL	51.437	4.014
	15.09.2010	VLISSGBISSVH	51.413	3.566
	17.09.2010	BOCHTVWTM	53.3357	6.9439
	22.09.2010	ROTTMPT70	54.118	6.213
	11.10.2010	HANSWGL	51.437	4.014
	11.10.2010	HUIBGOT	53.560	6.661
	11.10.2010	ROTTMPT3	53.566	6.563
	11.10.2010	VLISSGBISSVH	51.413	3.566
	13.10.2010	WALCRN70	51.957	2.678
	17.11.2010	NOORDWK70	52.586	3.530
	17.11.2010	WALCRN70	51.957	2.678
	18.11.2010	GOERE2	51.8469	3.9155
	18.11.2010	GOERE6	51.870	3.872
	23.11.2010	TERSLG50	53.768	4.766
	07.12.2010	VLISSGBISSVH	51.413	3.566
2011	27.04.2011	HANSWGL	51.437	4.014
	09.06.2011	HANSWGL	51.437	4.014
	16.06.2011	VLISSGBISSVH	51.413	3.566
	22.06.2011	HANSWGL	51.437	4.014
	27.06.2011	BOCHTVWTM	53.3357	6.9439
	04.07.2011	HANSWGL	51.437	4.014

Table 1 Table detailing occurrences and basic environmental factors at the time of occurrence *(Continued)*

	Date	Station	Latitude	Longitude
	04.07.2011	VLISSGBISSVH	51.413	3.566
	11.07.2011	BOCHTVWTM	53.3357	6.9439
	11.07.2011	HUIBGOT	53.560	6.661
	12.07.2011	ROTTMPT3	53.566	6.563
	18.07.2011	HANSWGL	51.437	4.014
	25.07.2011	BOCHTVWTM	53.3357	6.9439
	25.07.2011	GROOTGND	53.305	7.157
	25.07.2011	HUIBGOT	53.560	6.661
	01.08.2011	HANSWGL	51.437	4.014
	01.08.2011	VLISSGBISSVH	51.413	3.566
	08.08.2011	BOCHTVWTM	53.3357	6.9439
	10.08.2011	WISSKKE	51.602	3.721
	16.08.2011	HANSWGL	51.437	4.014
	23.08.2011	BOCHTVWTM	53.3357	6.9439
	29.08.2011	HANSWGL	51.437	4.014
	06.09.2011	BOCHTVWTM	53.3357	6.9439
	13.09.2011	HANSWGL	51.437	4.014
	13.09.2011	VLISSGBISSVH	51.413	3.566
	14.09.2011	GOERE2	51.8469	3.9155
	14.09.2011	GOERE6	51.870	3.872
	14.09.2011	WALCRN2	51.549	3.410
	15.09.2011	NOORDWK2	52.261	4.405
	20.09.2011	TERSLG50	53.768	4.766
	13.10.2011	SCHAARVODDL	51.351	4.251
	07.11.2011	SCHAARVODDL	51.351	4.251
2012	23.04.2012	HANSWGL	51.437	4.014
	07.05.2012	VLISSGBISSVH	51.413	3.566
	04.06.2012	HANSWGL	51.437	4.014
	02.07.2012	HANSWGL	51.437	4.014
	11.07.2012	ZIJPE	51.646	4.097
	16.07.2012	HANSWGL	51.437	4.014
	24.07.2012	WISSKKE	51.602	3.721
	29.07.2012	Sylt Roads	55.030	8.460
	30.07.2012	BOCHTVWTM	53.3357	6.9439
	30.07.2012	HANSWGL	51.437	4.014
	30.07.2012	VLISSGBISSVH	51.413	3.566
	27.08.2012	NOORDWK2	52.261	4.405
	28.08.2012	HANSWGL	51.437	4.014
	11.09.2012	BOCHTVWTM	53.3357	6.9439
	13.09.2012	HANSWGL	51.437	4.014
	13.09.2012	VLISSGBISSVH	51.413	3.566
	11.10.2012	HANSWGL	51.437	4.014
	11.10.2012	VLISSGBISSVH	51.413	3.566

Table 1 Table detailing occurrences and basic environmental factors at the time of occurrence *(Continued)*

	Date	Station	Latitude	Longitude
	18.10.2012	NOORDWK10	52.302	4.301
	25.10.2012	Sylt Roads	55.030	8.460
2013	20.06.2013	BOCHTVWTM	53.3357	6.9439
	25.06.2013	DREISR	51.715	3.999
	17.07.2013	BOCHTVWTM	53.3357	6.9439
	17.07.2013	HANSWGL	51.437	4.014
	31.07.2013	BOCHTVWTM	53.3357	6.9439
	31.07.2013	HANSWGL	51.437	4.014
	31.07.2013	VLISSGBISSVH	51.413	3.566
	14.08.2013	BOCHTVWTM	53.3357	6.9439
	14.08.2013	GROOTGND	53.305	7.157
	14.08.2013	HUIBGOT	53.560	6.661
	15.08.2013	WALCRN2	51.549	3.410
	30.08.2013	BOCHTVWTM	53.3357	6.9439
	30.08.2013	GROOTGND	53.305	7.157
	12.09.2013	VLISSGBISSVH	51.413	3.566
	13.09.2013	BOCHTVWTM	53.3357	6.9439
	13.09.2013	HUIBGOT	53.560	6.661
2014	26.02.2014	GROOTGND	53.305	7.157
	18.03.2014	WALCRN70	51.957	2.678
	12.05.2014	BOCHTVWTM	53.3357	6.9439
	18.06.2014	HANSWGL	51.437	4.014
	07.07.2014	BOCHTVWTM	53.3357	6.9439
	15.07.2014	HANSWGL	51.437	4.014
	15.07.2014	VLISSGBISSVH	51.413	3.566
	22.07.2014	HUIBGOT	53.560	6.661
	28.07.2014	HANSWGL	51.437	4.014
	28.07.2014	VLISSGBISSVH	51.413	3.566
	05.08.2014	HUIBGOT	53.560	6.661
	11.08.2014	HANSWGL	51.437	4.014
	11.08.2014	VLISSGBISSVH	51.413	3.566
	13.08.2014	SCHOUWN10	51.720	3.494
	25.08.2014	HANSWGL	51.437	4.014
	25.08.2014	VLISSGBISSVH	51.413	3.566
	05.09.2014	GROOTGND	53.305	7.157
	08.09.2014	HANSWGL	51.437	4.014
	08.09.2014	VLISSGBISSVH	51.413	3.566
	16.09.2014	WISSKKE	51.602	3.721
	18.09.2014	HUIBGOT	53.560	6.661
	05.12.2014	Sizewell	52.215	1.627
	05.12.2014	Sizewell	52.215	1.627
	05.12.2014	Sizewell	52.215	1.634
	03.05.2015	Helgoland Roads	54.180	7.900

Table 1 Table detailing occurrences and basic environmental factors at the time of occurrence *(Continued)*

	Date	Station	Latitude	Longitude
2015	27.05.2015	Sizewell	52.213	1.634
	26.07.2015	Sizewell	52.218	1.632
	26.07.2015	Sizewell	52.219	1.636
	23.09.2015	Sizewell	52.217	1.630
	23.09.2015	Sizewell	52.222	1.630
	23.09.2015	Sizewell	52.221	1.629
	23.09.2015	Sizewell	52.220	1.669
	23.09.2015	Sizewell	52.266	1.635
	22.10.2015	Sizewell	52.217	1.668
	22.10.2015	Sizewell	52.211	1.635
	22.10.2015	Sizewell	52.267	1.639
	31.10.2015	PS95 Stn 001	50.569	0.311
	01.11.2015	PS95 Stn 002	49.035	−5.990
	23.11.2015	Sizewell	52.219	1.668
	23.11.2015	Sizewell	52.222	1.629
	23.11.2015	Sizewell	52.220	1.667
	23.11.2015	Sizewell	52.268	1.641
	29.11.2015	L4	50.250	−4.210
2016	05.01.2016	L4	50.250	−4.210
	13.01.2016	L4	50.250	−4.210
	20.01.2016	E1	50.030	−4.360
	02.02.2016	L4	50.250	−4.210
	18.02.2016	E1	50.030	−4.360
	29.02.2016	L4	50.250	−4.210
	07.03.2016	L4	50.250	−4.210
	07.07.2016	Elbe 6 (F)	53.982	8.405
	25.10.2016	E1	50.030	−4.360
	01.11.2016	Helgoland Roads	54.180	7.900
	01.11.2016	L4	50.250	−4.210
	02.11.2016	Helgoland Roads	54.180	7.900
	07.11.2016	Helgoland Roads	54.180	7.900
	08.11.2016	Helgoland Roads	54.180	7.900
	14.11.2016	Helgoland Roads	54.180	7.900
	17.11.2016	Helgoland Roads	54.180	7.900
	18.11.2016	Helgoland Roads	54.180	7.900
	05.12.2016	L4	50.250	−4.210
	06.12.2016	E1	50.030	−4.360
	12.12.2016	L4	50.250	−4.210
	19.12.2016	L4	50.250	−4.210

and recently also in the harbour of Antwerp. This is also supported by the fact that during the periods of occurrence other benthic or ptychopelagic species (the latter defined as species that have a predominantly benthic

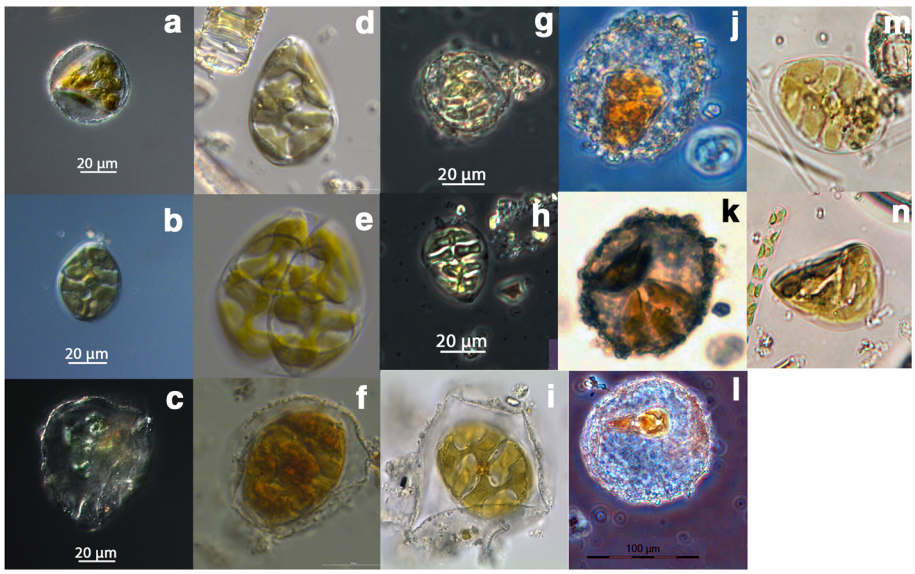

Fig. 2 Examples of image material for the 'pringle' from different locations: **a-b:** Helgoland Roads, **c:** Helgoland transect station Elbe 6, **d-f:** Station **L4** in the English Channel; **g-h:** PS95 Stn 1, **i.** Goeree 6, **j-l:** Lugol-fixed cells from Sizewell (CEFAS), **m-n:** Sylt Roads. Images a, b, d, e, l, m and n were obtained from live samples; images f, j, k, were obtained from Lugol's-fixed samples, image c refers to a Formalin-fixed specimen. Images **c, f, g, j, k** and **l** show cells encased in a mucilage envelope **Image credits:** a-c, g-h.: A. Kraberg, d-f: C. Widdicombe, j-l: R. Beckett, i. R. van Wezel, m,n: J. Rick

mode of life but can appear in the plankton e.g. after extreme weather events) were also often present including *Paralia sulcata*, *Actinocyclus* and *Odontella* species, (data not shown but see Fig. 1d). Assuming that the taxon considered here is indeed *Plagiolemma distortum*, this would also fit with the observations by Nezan et al. (2018) who considered this taxon as potentially benthic or epilithic. But clearly, more sustained observations with a good spatial coverage, appropriate image metadata and preferentially sequence data, are necessary to reveal in more detail the taxonomic position and ecology of this enigmatic species.

Conclusion

The number of actual distributional records is still very small, spread over a number of years and more data are therefore required to confirm the origin and main direction of spread of this taxon from the North Atlantic into the North Sea via the English Channel (or vice versa extended its range from more brackish habitats into the open sea). It is also unclear whether first records were really first records or mark the point where an unidentified cell was first recorded as a distinct taxon in a given time series. Importantly, beginning to chart the progress of this species was possible because of the large number

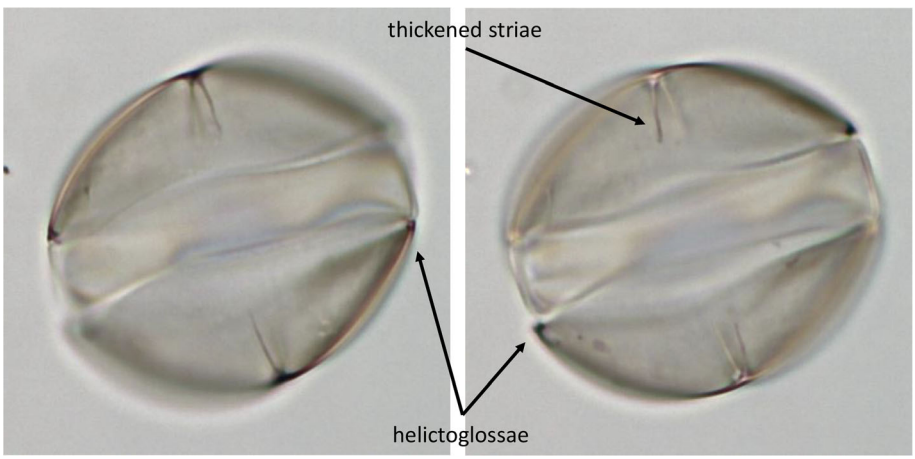

Fig. 3 Two cleaned valves mounted in Zrax resin, images 20×/0.7 brightfield microscopy, sample was obtained from the Western Scheldt, July 13th 2015, cell length 42 µm, image source: R. van Wezel

of available high-quality records documented with image material. Adhering to a strict protocol for recording new or unidentified taxa photographically and with appropriate taxonomic and biogeographic meta data is therefore strongly recommended for any time series programme routinely determining phytoplankton abundance (Zingone et al. 2015) both to increase the taxonomic consistency and resolution within time series but also to facilitate more detailed comparisons between data sets.

Abbreviations

AWI: Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research; GIS: Geographic information system; HAB: Harmful algal blooms; ICES: International Council for the exploration of the seas; NERC: UK Natural Environment Research Council; TWN: Taxon management the Netherlands; WGPME: Working group on phytoplankton and microbial ecology

Acknowledgements

AK was funded by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research. CW and PR were funded under the UK's Natural Environment Research Council (NERC) National Capability programme. We also acknowledge the International Council for the Exploration of the Seas (ICES) for supporting the Working group on Phytoplankton and Microbial Ecology (WGPME). The manuscript was planned and its first version written during the annual WGPME meeting in Reikjavik 2017. We thank Silvia Peters at the Biologische Anstalt Helgoland (AWI), Malte Elbrächter and Hanne Halliger at the Waddenseastation Sylt and all the past and present analysts of the time-series stations referred to in this study. We further thank Dr. Dario Fiorentino of the Helmholtz Institute for Functional Marine Biodiversity (HIFMB) for the production of the distribution map. We also thank two anonymous reviewers for their valuable comments.

Funding

UK Natural Environment Research Council (NERC) National Capability programme.

Availability of data and materials

Image material is published in the open access data base Planktonnet (http://planktonnet.awi.de). The geolocations are already freely available. No other data were used.

Authors' contributions

The manuscript arose from discussions between AK and CW. AK wrote the first draft. All authors contributed image material from their time series station and contributed to the discussion of the identity of the taxon. Final editing was done by AK with contributions from RW, RB and CW. All authors read and approved the final manuscript.

Ethics approval and consent to participate

NA

Consent for publication

All authors have given consent to publishing the MS.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Author details

[1]Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Biologische Anstalt Helgoland, Kurpromenade 201, 27498 Helgoland, Germany. [2]Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, UK. [3]Centre for the Environment, Fisheries and Aquaculture Science, Lowestoft, UK. [4]Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Wattenmeerstation Sylt, Hafenstraße 43, 25992 List/Sylt, Germany. [5]Rijkswaterstaat, Ministry of Infrastructure and Watermanagement, Lelystad, The Netherlands.

Received: 18 May 2018 Accepted: 19 August 2018
Published online: 21 September 2018

References

Cohn SA, Weitzell RE Jr. Ecological considerations of diatom motility. I. Characterization of motility and adhesion in four diatom species. J Anim Ecol. 1996;32 https://doi.org/10.1111/j.0022-3646.1996.00928.x.

Edgar LA, Pickett-Heaps JD. The mechanisms of diatom locomotion. I. An ultrastructural study of the motility apparatus. Proceedings of the Royal Society London. 1983;218:331–43.

Franke H-D, Gutow L. Long-term changes in the macrozoobenthos around the rocky island of Helgoland (German bight, North Sea). Helgol Mar Res. 2004; 58:303–10.

Hoppenrath M. A revised checklist of planktonic diatoms and dinoflagellates from Helgoland (North Sea, German bight). Helgol Mar Res. 2004;58:243–51.

Minchin D, Cook EJ, Clark PF. Alien species in British brackish and marine waters. Aquat Invasions. 2013;8:3–19.

Nezan E, Bilien G, Boulben S, Mertens KN, Chomerat N (2018) Desription and phylogenetic position of Plagiolemma distortum sp. nov., a new raphid diatom (Bacillariophyceae) from French coastal waters Diatom Research https://www.tandfonline.com/doi/full/10.1080/0269249X.2018.1468359

Rademaker M, Koeman R (1992) Determinatie fytoplankton in het Nederlandse deel van de Noordzee en het kanaal project algenbloei 1992. 23pp. Bureau Tripos, Amsterdam.

Veen A, Hof CHJ, Kouwets FAC, Berkhout T (2015) Rijkswaterstaat Waterdienst, Informatiehuis Water [Taxa Watermanagement the Netherlands (TWN)] http://ipt.nlbif.nl/ipt/resource?r=checklist-twn, consulted: 14.5.2018.

Widdicombe C,E, Eloire D, Harbour D, Harris RP, Somerfield PJ. Long-term phytoplankton community dynamics in the western English Channel. J Plankton Res. 2010;32:643–55.

Wiltshire KH, Kraberg A, Bartsch I, Boersma M, Franke HD, Freund J, Gebühr C, Gerdts G, Stockmann K, Wichels A (2010) Helgoland Roads: 45 years of change in the North Sea Estuaries and Coasts https://doi.org/10.1007/s12237-009-9228-y.

Zingone A, Harrison PJ, Kraberg AC, Lehtinen S, McQuatters-Gollop A, O'Brien T, Sun J, Jakobsen HH. Increasing the quality, comprability and accessibility of phytoplankton species composition time-series data. Estuar Coast Shelf Sci. 2015;162:151–60.