

SHORT NOTE

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Chaetoceros resting spores in the Gerlache Strait, Antarctic Peninsula

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Abstract The formation of resting spores in diatoms is a common phenomenon in neritic environments. Here we report on resting spores of the genus *Chaetoceros* associated with a layer of increased chlorophyll fluorescence, at a depth of more than 200 m, north of Brabant Island and in Wilhelmina Bay, southeast coast of the Gerlache Strait (64°41.0'S, 62°0.5'W). Six species of *Chaetoceros* were identified by the morphology and size of the resting spores. Given that *Chaetoceros* spp., both in vegetative cells and as resting spores, are commonly found in Antarctic coastal surface waters, their location at depth could represent the pelagic "waiting" or "seeding" populations mentioned for other environments.

Introduction

Resting spore formation in diatoms is a common phenomenon in neritic environments (e.g. Garrison 1981). Algal resting spores, including those from diatoms, are usually formed under environmental stress, such as light or nutrient limitation (e.g. Hargraves and French 1983). Resting spores in *Chaetoceros* have previously been observed to be abundant in sediment traps and sediments in the Gerlache and Bransfield Straits, western Antarctic Peninsula (Leventer 1991). In this study, we determine pelagic species of *Chaetoceros* resting spores found at depth in the water column ($z > 210$ m) in the vicinity of Gerlache Strait, characterize the chemical and

physical environment in which they were found, and discuss our observations in view of the current hypotheses on behavior and formation of resting spores.

Materials and methods

Three of the 37 stations visited in the Gerlache and southern Bransfield Straits were sampled during a cruise on board the R/V "Polar Duke" on 6 and 25 November 1989 for this study: FD06 (64°41.0'S, 62°0.5'W), $z = 370$ m; FD13 (63°55.0'S, 62°22.5'W), $z = 240$ m; FD14 (63°50.0'S, 62°21.9'W), $z = 285$ m. Station FD06 was located in Wilhelmina Bay and stations FD13 and FD14 were north of Brabant Island (Fig. 1). In addition to surface waters, samples for diatom spores were taken at 313, 200, and 265 m, respectively, in 10-l Niskin bottles attached to the CTD rosette which included beam transmission (SeaTech 25-cm transmissometer).

For taxonomic identification and quantitation, samples (4,270 ml seawater) were concentrated on a Nuclepore filter, 0.4- μ m pore size, preserved in 2% formalin, and resuspended in 50 ml filtered seawater. Subsequently, filters soaked in immersion oil to make them clear were observed under the microscope to ensure no cells, valves or spores were left. The resuspended sample was sedimented in a 50-ml cylinder and cells were counted by the Utermöhl (1958) method. A Zeiss inverted microscope, with phase contrast illumination, was used for quantitative analysis. Species identification was performed with a Zeiss Standard microscope with phase contrast illumination, with a subsample mounted in Naphrax (refractive index of 1.74, Northern Biological Supplies) (Hasle 1978). Chlorophyll *a* and phaeopigments were measured with a Turner Designs AU-10, following Holm-Hansen et al. (1965).

Results

From the 37 stations visited in November 1989, only the 3 stations presented here showed a decrease in beam transmission at depth with respect to overlying waters. At st. FD06 in Wilhelmina Bay, we observed a decrease in beam transmission from 86% to 82% in the interval 150- to 300-m depth (Table 1). The decrease in beam transmission can be attributed to an increase in suspended particles, either biotic or abiotic. Chlorophyll *a*

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concentration in the same station increased also for the same depth range, from 0.26 to 0.38 mg m⁻³ (Table 1), indicating the presence of living phytoplankton in this layer. In the southern Bransfield Strait, we observed increased beam transmission at depth, similar to Wilhelmina Bay, but it was not associated with an increased

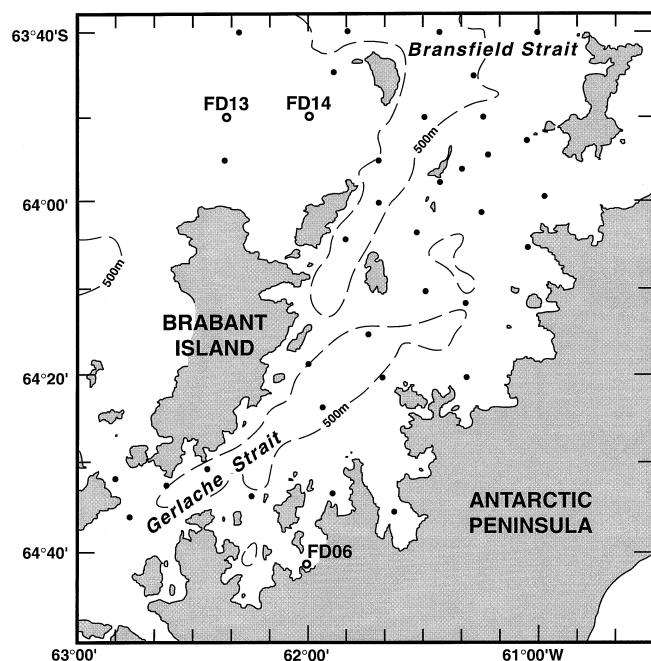


Fig. 1 Map of the Research on Antarctic Coastal Ecosystem Rates (RACER) grid sampled during November 1989 showing the three stations where indications of deep phytoplankton populations were encountered

Table 1 Transmission properties and pigment concentration at the stations sampled at depth. Chlorophyll *a* (*Chl a*) and phaeopigment (*Phaeo*) in mg m⁻³. Percent transmission as measured by a SeaTech transmissometer (*n.a.* not available)

Station	Depth (m)	<i>Chl a</i>	<i>Phaeo</i>	% Transmission
FD06	0	23.25	5.75	41.20
	50	0.65	0.51	84.13
	100	0.25	0.20	85.90
	150	0.26	0.18	86.03
	200	0.25	0.12	85.92
	250	<i>n.a.</i>	<i>n.a.</i>	86.10
	313	0.38	0.23	84.67
FD13	0	1.10	0.12	80.71
	50	0.23	0.13	85.49
	100	0.19	0.12	86.37
	150	0.07	0.09	85.74
	200	0.05	0.10	83.18
	215	0.05	0.10	82.42
FD14	0	1.46	0.21	78.54
	50	0.3	0.14	85.87
	100	0.17	0.11	86.19
	150	0.09	0.12	86.23
	200	0.05	0.05	86.08
	250	<i>n.a.</i>	<i>n.a.</i>	83.94
	265	0.06	0.14	80.15

chl fluorescence or chl *a* concentration. In all three stations, the ratio of phaeopigments to chl *a* at depth was 0.6, 2.0 and 2.33 at sts. FD06, FD13, and FD14 respectively, compared to ratios at the surface of 0.25, 0.11, and 0.14, suggesting more degraded material at depth than at the surface. This ratio also indicates more degradation at depth in the area north of Brabant Island than in Wilhelmina Bay.

Biological and chemical characteristics in the surface water column, above the maximum of chlorophyll fluorescence at depth, indicated active phytoplankton growth. Chlorophyll *a* concentrations at the surface were 23.3 mg m⁻³ at st. FD06, and 1.1 and 1.46 mg m⁻³ at sts. FD13 and FD14, respectively (Table 1). Surface waters at Wilhelmina Bay had depleted nitrate at the surface, from 28.7 μM at depth to <1 μM at 1 m, and silicic acid decreased from 86 μM at 313 m to 49.2 μM. North of Brabant Island, surface waters showed decreased silicic acid concentrations from 86.9 μM at depth to 74.3 and 68.4 μM, and nitrate concentrations also decreased from 30.5 μM at depth to 26 and 24.9 μM at surface, for sts. FD13 and FD14, respectively.

Chaetoceros resting spores dominated the deep phytoplankton assemblage at Wilhelmina Bay (st. FD06). *Chaetoceros compressus*, *C. curvisetus*, *C. neglectus*, and *C. socialis* accounted for 90% of the spores encountered (Table 2). The other 10% were *C. ceratosporus* and *Chaetoceros* sp. A. *Chaetoceros* species determinations were made considering only morphological characteristics of the resting spores, due to the absence of vegetative cells.

1. *Chaetoceros ceratosporus* Ostenfeld. Hustedt 1930: pp. 760–761, Fig. 442; Rines and Hargraves 1986: p. 104, Pl. 1, Figs. 1–2. Morphometric observations: apical axis, 16–17 μm; perivalvar axis, 7.0–7.5 μm.

2. *Chaetoceros compressus* Lauder. Rines and Hargraves 1988: pp. 64–67, Fig. 131. Morphometric observations: apical axis, 7–9.3 μm; perivalvar axis, 5.5–8.0 μm.

3. *Chaetoceros neglectus* Karsten. Stockwell 1991, Pl. 1, Figs. 1–6; Hasle and Syvertsen 1996: p. 207, Pl. 44. Morphometric observations: apical axis, 12–18 μm; perivalvar axis, 7–9 μm.

4. *Chaetoceros socialis* Lauder. Cupp 1943: p. 143, Fig. 100c; Hasle and Syvertsen 1996: p. 221, Pl. 47.

Table 2 Abundance of *Chaetoceros* resting spores found in station FD06 in Wilhelmina Bay

Species	Cells l ⁻¹	Percent abundance
<i>Chaetoceros ceratosporus</i> Ostenfeld	8	0.8
<i>Chaetoceros compressus</i> Lauder	371	35.4
<i>Chaetoceros cf. curvisetus</i> Cleve	187	18.0
<i>Chaetoceros neglectus</i> Karsten	171	16.3
<i>Chaetoceros socialis</i> Lauder	196	18.6
<i>Chaetoceros</i> sp. A ^a	114	10.9
Total	1047	100.0

^aStockwell 1991

Morphometric observations: apical axis, 4–6 μm ; perivalvar axis, 4–6 μm .

5. *Chaetoceros* sp. A. Stockwell 1991, Pl. 2, Figs. 1–6. Morphometric observations: apical axis, 7.4–20.0 μm ; perivalvar axis, 4.5–9.5 μm .

6. *Chaetoceros* cf. *curvisetus* Cleve. Cleve Euler 1951: p. 100, Fig. 194. Morphometric observations: apical axis, 13–14 μm ; perivalvar axis, 4–5 μm .

In addition to the *Chaetoceros* resting spores found at Wilhelmina Bay, we observed *Thalassiosira* sp., *Actinocyclus actinochilus* (Ehrenberg) Simonsen, *Stellarima microtrias* (Ehrenberg) Hasle and Sims, *Corethron criophilum* Castracane, *Fragilariopsis cylindrus* (Grunow) Krieger, *F. curta* (Van Heurck) Hustedt, *Achnanthes* sp., and *Navicula* sp., but these valves accounted for <5% of all counts.

At the stations located north of Brabant Island, in southern Bransfield Strait (sts. FD13, FD14), we did not observe spores or vegetative valves of *Chaetoceros* spp. More abundant diatom valves corresponded to pelagic species of *Thalassiosira gracilis* (Karsten) Hustedt, *Thalassiosira* spp., *Fragilariopsis cylindrus* (Grunow) Krieger, *F. curta* (Van Heurck) Hustedt, *F. kerguelensis* (O'Meara) Hustedt, *Actinocyclus actinochilus* (Ehrenberg) Simonsen, and *Actinocyclus* sp. Benthic species included *Cocconeis fasciolata* (Ehrenberg) Brown, *Diplooneis* sp., and *Entopyla* sp.

Discussion

In our area, as found in other studies from temperate and tropical waters (Bienfang 1981; Garrison 1981), resting spores occurred in an environment where surface plankton experienced nutrient limitation, although this is not a common scenario in Antarctic waters. In general, low light conditions have been identified as an important triggering mechanism for spore formation in polar waters such as those found where cells are mixed or sink below the pycnocline (von Bodungen et al. 1986), as well as where diatoms are exposed to variable mixing regimes (Pitcher 1990). Given that *Chaetoceros* spp., both in vegetative cells and as resting spores, are commonly found in surface waters in the Gerlache Strait (Ferrario and Sar 1992), the spores observed at depth could represent the pelagic “waiting” or “seeding” populations (Smetacek 1985). Garrison (1981) and Pitcher (1986) suggested that phytoplankton resting spores could be retained in the pelagic environment and would not necessarily reach the bottom, as first hypothesized by Gran (1912). Our observations cannot differentiate between spores resuspended from the sediments and those that never reached the bottom. As no lithogenic material was observed in the samples, the spores might have remained in suspension after sedimenting from surface waters.

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