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Large red cyanobacterial mats (*Spirulina subsalsa* Oersted ex Gomont) in the shallow sublittoral of the southern Baltic

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Abstract

We report the first observation of large red cyanobacterial mats in the southern Baltic Sea. The mats (up to 2.5 m in diameter) were observed by SCUBA divers at 7.7 m depth on loamy sediments in the Gulf of Gdańsk in mid-November 2013. The main structure of the mat was formed by cyanobacteria *Spirulina subsalsa* Oersted ex Gomont; a number of other cyanobacteria, diatoms and nematode species were also present. After a few days in the laboratory, the red trichomes of *S. subsalsa* started to turn blue-green in colour, suggesting the strong chromatic acclimation abilities of this species.

The complete text of the paper is available at http://www.iopan.gda.pl/oceanologia/

Large algal mats were found on the shallow bottom (at 7.7 m depth) in the coastal waters near the cliff in Gdynia Orłowo (18°35′N, 54°28′E, Figure 1) during an underwater survey by SCUBA divers on 15 November 2013 (Figures 2a,b). The bright red algal mats were patchily distributed on the loamy sea bottom with the largest patches reaching an area of 2.5 m^2 (as measured on images calibrated with the use of diving computer placed on the bottom for reference). The flat, thin (1–2 mm) mats were cohesive but soft – they did not adhere closely to the sediment. Instead, they could be easily removed from the substrate, and the edges of the largest mats were in some places hanging loose over the bottom. The water temperature (measured with a UWATEC Aladin TEC 2G diving computer) was 8°C. The samples of algal mats collected by divers were analysed live under a Nikon Ti-S inverted microscope equipped with a water immersion objective of magnification 60x and differential interference contrast. The main mat structure was formed by cyanobacteria identified as *Spirulina subsalsa* Oersted ex Gomont (Komárek & Anagnostidis 2005). The *Spirulina* trichomes were 2.3 μm wide and formed tightly coiled spirals (spiral height – 5.43 μm) of a pinkish-red colour (Figure 2d). Living trichomes glided with screw-like movements over the substratum, performing oscillatory movements. The mat also contained other cyanobacteria species: *Phormidium formosum* (Bory ex Gom.) Anagn. ex Kom., *P. tergestinum* (Kütz.) Anagn. et Kom., *Pseudanabaena galeata* Böcher, *Leptolyngbya* sp., and diatoms belonging to the genera *Bacillaria*, *Navicula*, *Cymbella*, *Cocconeis*, *Melosira* and *Coscinodiscus*, as well as large numbers of nematodes.

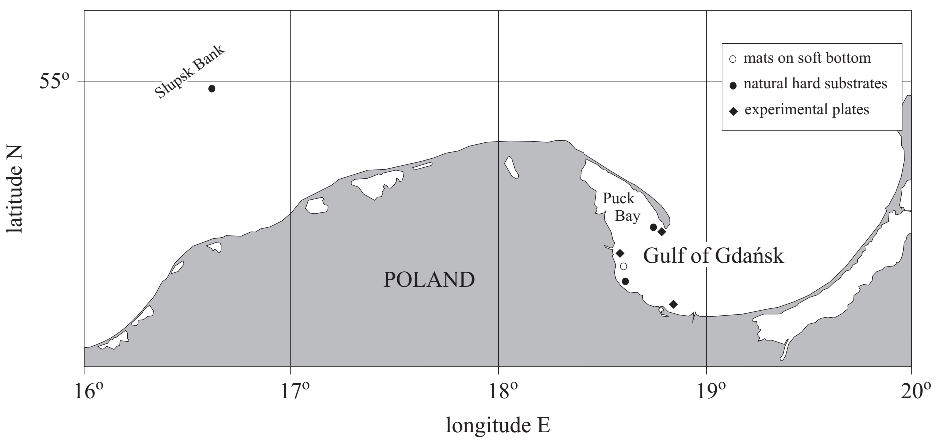

Figure 1. Locations in the Polish Exclusive Economic Zone where *Spirulina* mats were observed in natural habitats (present study) or on experimental colonisation plates (after Dziubińska & Janas 2007, Dziubińska & Szaniawska 2010)

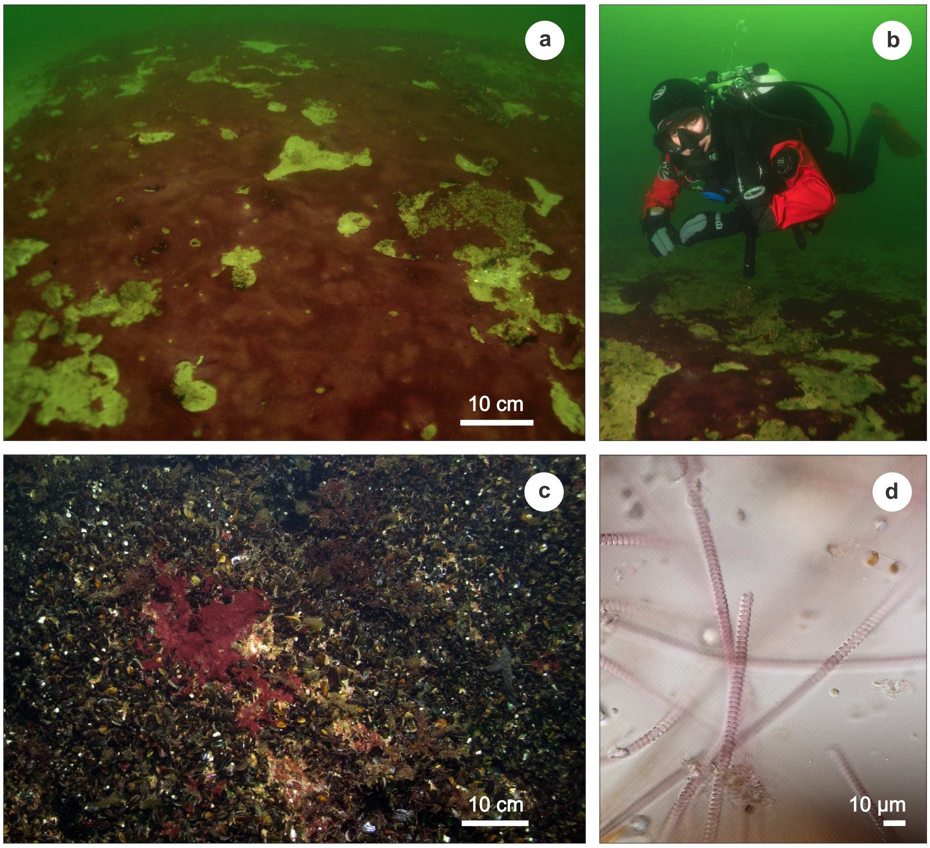

Figure 2. Algal mats of *Spirulina subsalsa* on the loamy bottom near Gdynia Orłowo (a,b) and on blue mussel beds on the Słupsk Bank (c). d) Filaments of *Spirulina subsalsa* obtained from the algal mat. Photos: a,b,c – Piotr Balazy, d – Józef Wiktor

The same team of divers (the first two authors) noted the occurrence of similar red mat-like structures, yet of much smaller size (a few cm in diameter), covering blue mussel (*Mytilus* spp.) aggregations overgrowing hard bottom structures in Polish coastal waters. These observations were made in autumn 2013, on natural stone and pebble deposits on the Słupsk Bank (54°59′N, 16°40′E, 13 m depth, 18 September, water temp. 17°C, Figure 2c), in the shallow waters off Sopot (54°26′N, 18°35′E, 5 m depth, 17 December, water temp. 4°C) and on the wreck of the ORP 'Wicher' lying off the Hel Peninsula (54°36′N, 18°46′E, 3 m depth, 13 October, water temp. 9°C, Figure 1).

The present finding is exceptional owing to the size of algal mats and their presence on the loamy flat seabed. According to a number of divers consulted (Andrulewicz, pers. comm.), such structures were never observed before on the bottom in Polish waters. To our knowledge, neither were such cyanobacterial mats reported to occur in other regions of the Baltic Sea. Species of genera *Spirulina* occur in marine biotopes, and in inland salty and brackish stagnant waters worldwide (Komárek & Anagnostidis 2005). *Spirulina* spp. has been common in fully marine waters off the Atlantic coast from France to Norway (Rathsack-Künzenbach 1961, Komárek & Anagnostidis 2005), whereas it may be a relatively recent newcomer to the Gulf of Gdańsk (Pliński & Komárek 2007). *Spirulina* spp. have been recorded on natural hard substrates in other parts of the Baltic Sea, e.g. on boulders in the Asko area (Wallin et al. 2011), on ascidians in Gullmar Fjord, Skagerrak (Johansson et al. 1998) or on barnacles *Balanus improvisus* off the island of Rügen, where they formed small mat-like patches up to 3 cm in diameter (Rathsack-Künzenbach 1961). Rose-pink trichomes of *Spirulina rosea* Crouan were found on experimental colonisation plates deployed in the Gulf of Gdańsk at locations close to Gdynia and Gdańsk (Dziubińska & Janas 2007) and Hel (Dziubińska & Szaniawska 2010). *Spirulina major* Kützig was recorded in the southern Baltic and in Puck Bay (Pliński 1975, Ringer 1984). Solitary blue-green trichomes of *S. subsalsa* were noted earlier in Puck Bay (Witkowski 1993).

Our observations were made in mid-November, when the sun was relatively low above the horizon (solar elevation angle at noon – 17°) and the day length did not exceed 9 hours. After a few days in the laboratory at a photosynthetically active radiation (PAR) of 10 μE m^{-2} s^{-1}, red trichomes of *S. subsalsa* started to change colour to blue-green. Such a change in colour is possible as cyanobacteria have a wide range of pigment compounds, including carotenoids, chlorophyll and phycobiliproteins (red phycoerythrin and blue phycocyanin). Chromatic acclimation in cyanobacteria, i.e. their ability to adapt to changing characteristics of the spectral distribution of ambient light, was described e.g. by Gutu & Kehoe (2012). Indeed, because of the optical properties of seawater, cells at the surface and in deeper parts of the water column experience different light conditions in terms of both the amount (intensity) and quality (colour) of light resources. Dera & Woźniak (2010) showed that already at a depth of 6 m in the Baltic Sea the spectrum of PAR irradiance becomes narrower, as the long waves are attenuated by water molecules; the mean daily dose of downward irradiance in PAR also decreases dramatically with water depth: in November it is 10 times lower at 8 m depth than at the water surface. *Spirulina* can react to such differences in light conditions by changing its pigment compound composition and increasing or decreasing the proportion of phycobiliproteins.

It is worth noting that all the observations of red *Spirulina* reported here were made in autumn (from mid-September to mid-November). Dziubińska & Janas (2007) and Dziubińska & Szaniawska (2010) studied the seasonality in composition of fouling communities on experimental plates deployed at three sites in the Gulf of Gdańsk. In spring and summer *Spirulina* was not present on any of them. It appeared on the plates only in autumn, i.e. September or October, depending on the site and year. The autumnal development of mats of phycoerythrin-rich *S. subsalsa* in this area is possible as a result of chromatic adaptation (also responsible for the red colour of trichomes). Obviously, this taxon can utilise low PAR and thus supply organic carbon to the benthic system in seasons when the pelagic primary producers are less active. It remains unknown whether such mats can persist all the year round in this region, and if not, what triggers their seasonal development. Extensive coverage of the seabed by cyanobacterial mats is apparently a new phenomenon in this region with interesting implications for the seabed fauna (sediment stabilisation, gas exchange, organic matter enrichment) that make them worthy of further investigation.

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