Research Note

Photosynthesis and respiration of some marine benthic algae from Spitsbergen

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Light-photosynthesis curves for 9 species of benthic algae from the Hornsund fiord were determined. As a result of adaptation to the conditions in the Arctic, benthic algae from Spitsbergen have a low requirement of light. Saturation and compensation points are low and within a range typical for shadow-tolerant plants. The values for gas exchange rates indicate that Arctic algae have lower photosynthetic capacity than temperate species.

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In spite of unfavourable light and temperature due to long dark winters and a small incident sun angle in summer, communities of benthic algae are abundant in Arctic waters. Another factor which limits availability of light in the Arctic environment is the ice cover, which frequently lasts for more than 6 months. Benthic algae growing in such harsh conditions should be expected to exhibit special climatic adaptations, as for instance reflected in the rate of gas exchange.

Information on photosynthesis and respiration of multicellular benthic algae in the Arctic is rather sparse. However, Healey (1972) and Prahl (1979) have published data on this subject. Also Kanwisher (1966) examined and reported respiration rates in two Phaeophyta species.

The aim of the present work was to determine respiration and photosynthetic rates in several species which are abundant in the littoral zone of the Hornsund fiord (Florczyk & Latała 1989).

Material and methods

All specimens were collected at Isbjørnhamna Bay, which is situated in the central part of the Hornsund fiord, southwestern Spitsbergen (77°N, 15°62'E). The following 6 species of brown algae were investigated: *Pilayella littoralis* (Linneaus) Kjellman, *Chordaria flagelliformis* (O. F. Muller) C. A. Agardh, *Chorda tomentosa* Lyngbye, *Alaria grandifolia* J. Agardh, *Fucus distichus* subsp. *evanescens* Linneaus emend. Powell, *Laminaria digitata* (Hudson) Lamouroux, as well as two species of green algae: *Acrosiphonia duriuscula* (Ruprecht) Yendo and *Ulvaria obscura* (Kutzing) Gayral and one species of red algae: *Dumontia incrassata* (Muller) Lamouroux.

Measurements were performed in August 1983. Manual collection was carried out in the littoral zone at the rocky shore and only three species (*Ulvaria obscura, Alaria grandifolia* and *Laminaria digitata*) were collected by means of a small anchor from the sublittoral zone at a depth of c. 5 m. The algal thalli (without macroscopic epiphytes) were collected immediately before measurement.

Light-photosynthesis curves were determined with an improved version of volumetric microrespirometer (Zurzycki & Starzecki 1971). The method enables evaluation of gas exchange (photosynthesis and respiration) in small biological objects, and allows the estimation of production or consumption of oxygen at rates varying from 10^{-1} to 10^{-4} μl O_2 * h^{-1} with an accuracy of ±5%. CO_2 concentration in the reaction microchamber was kept constant with 35 μl of 0.1 N Warburg No. 10 carbonate buffer. The light source was a Narva bulb (220V, 250W) which in the reaction chamber yields a maximum intensity of 30 klx. Infra-red radiation was removed by a 50 mm thick liquid filter containing 140 g ferrous ammonium sulphate in one litre of 2% H_2SO_4. A combination of neutral filters and iris diaphragms was used to obtain different light intensities. Light intensities were measured with a JU-16 luxmeter. For the optical micro-respirometer system the luxmeter was additionally calibrated against a Lambda Li Cor Li-185 radiometer. It was calculated that 1 $W^* \ m^{-2}$ (PAR) corresponded with 4.95 $\mu E \ * \ m^{-2*} \ s^{-1}$ (PAR) or c. 205 lx. Measurements were carried out at a constant temperature of 3 ± 0.1°C, the same as the surface sea water temperature at the time of collection. Constant temperature was maintained with an ultrathermostat equipped with a cooler.

Thallus pieces of several milligrams fresh weight were placed in natural sea water of 32–33‰ salinity. In the case of algae with multilayer thallus, pieces from the upper part were used. The gas exchange rates of intact algae and thallus pieces showed great similarity (Brinkhuis 1977a, b) because these organisms exchange gases at the whole surface of their assimilating organs. For this reason, pieces of benthic algae are widely applied in different techniques for photosynthesis and respiration measurements (King & Schramm 1976; Kanwisher 1966; Merrill & Waaland 1979). Algal biomass was determined as fresh weight (mg) and the gas exchange was expressed as $\mu l \ O_2 \ * \ h^{-1*} \ mg^{-1}$.

Several (3–6) measurements were performed with each species and variations from the mean value of oxygen evolution were generally less than 10%.

Results and discussion

Maximum photosynthetic rates ranged from 0.045–0.62 $\mu l \ O_2 * h^{-1} * mg^{-1}$fr.wt. (Fig. 1, Table 1). Oxygen consumption ranged from 0.035–0.305 $\mu l \ O_2 * h^{-1} * mg^{-1}$. The highest photosynthetic rate as well as the highest photosynthesis : respiration ratio was observed for the filamentous brown algae *Pilayella littoralis*. *Acrosiphonia duriuscula* and *Ulvaria obscura* also exhibited very high photosynthetic rates. The lowest rates were observed in two brown algae with coriaceous thalli, *Laminaria digitata* and *Fucus distichus*. These results confirm the principle that perennial algae with multilayer and coriaceous

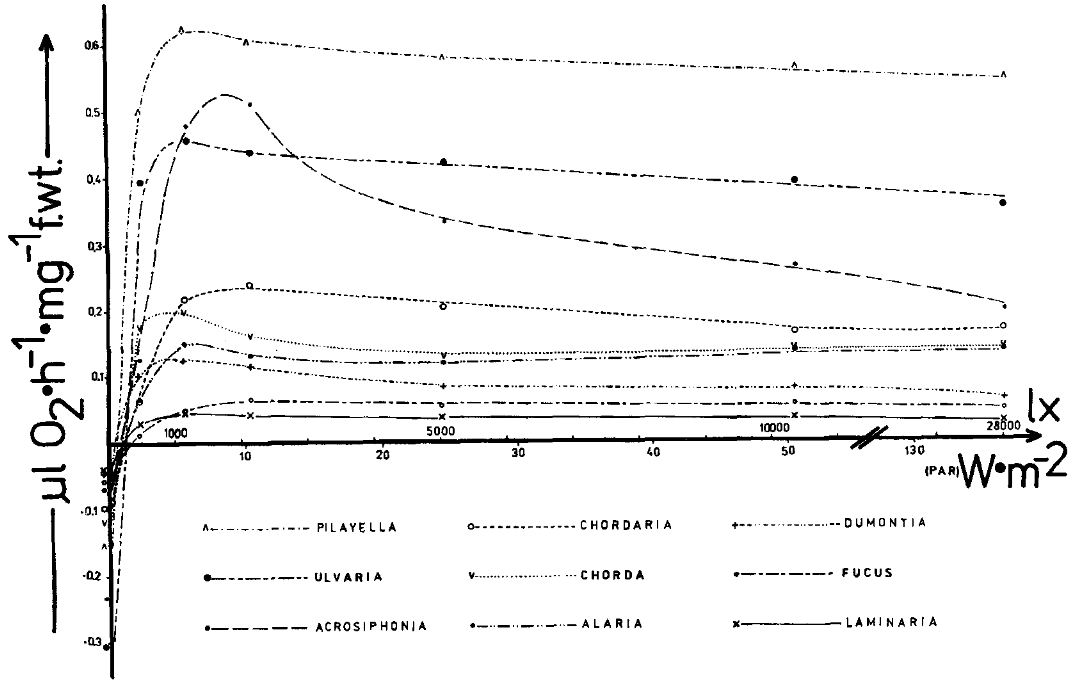

Fig. 1. Light-photosynthetic curves in benthic algae from Spitsbergen.

Table 1. Comparison of parameters for gas exchange in benthic algae from the Hornsund fiord, SW Spitsbergen, Disco Island, W Greenland (Prahl 1979) and the Gdańsk Bay (Latała 1982).

Species	Hornsund fiord (Aug. t = 3°C)					Disco Island (July t = 5°C)					Gdansk Bay (Apr./May t = 5°C)				
	Pm	R	Pm/R	Pc	Ps	Pm	R	Pm/R	Pc	Ps	Pm	R	Pm/R	Pc	Ps
Green algae															
Acrosiphonia arcta	—	—	—	—	—	0.19	−0.03	6.5	500	10,000	—	—	—	—	—
Acrosiphonia duriuscula	0.515	−0.235	2.2	300	2,000	—	—	—	—	—	—	—	—	—	—
Cladophora rupestris	—	—	—	—	—	—	—	—	—	—	0.41	−0.11	3.7	200	3,500
Enteromorpha intestinalis	—	—	—	—	—	—	—	—	—	—	1.81	−0.495	3.6	800	7,000
Ulotrix implexa	—	—	—	—	—	—	—	—	—	—	1.24	−0.381	3.3	500	3,000
Ulotrix speciosa	—	—	—	—	—	1.25	−2.03	0.65	2,000	30,000	—	—	—	—	—
Ulvaria obscura	0.465	−0.305	1.5	200	1,000–2,000	—	—	—	—	—	—	—	—	—	—
Urospora penicilliformis	—	—	—	—	—	0.53	−0.45	1.1	3,000	60,000	—	—	—	—	—
Brown algae															
Alaria grandifolia	0.155	−0.07	2.2	250	1,000–2,000	—	—	—	—	—	—	—	—	—	—
Chorda filum	—	—	—	—	—	—	—	—	—	—	0.845	−0.11	7.7	150	5,000
Chorda tomentosa	0.205	−0.12	1.7	250	1,000	—	—	—	—	—	—	—	—	—	—
Chordaria flagelliformis	0.265	−0.1	2.6	250	2,000	0.61	−0.12	5	1,000	70,000	—	—	—	—	—
Fucus distichus	0.065	−0.06	1.1	350	2,000–3,000	0.27	−0.018	15	1,500	50,000	—	—	—	—	—
Fucus vesiculosus	—	—	—	—	—	—	—	—	—	—	0.212	−0.096	3.5	400	2,000
Laminaria digitata	0.045	−0.035	1.3	200	1,000–2,000	—	—	—	—	—	—	—	—	—	—
Pilayella littoralis	0.62	−0.155	4	100	1,000–2,000	0.36	−0.083	4.2	1,000	40,000	0.485	−0.245	2	400	2,000
Red algae															
Dumontia incrassata	0.135	−0.045	3	100	1,000–2,000	—	—	—	—	—	—	—	—	—	—

Abbreviations: Pm – max. photosynthesis (µl $O_2 * h^{-1} * mg^{-1}$ f.wt.); R – dark respiration (µl $O_2 * h^{-1} * mg^{-1}$ f.wt.); Pc – compensation point (lx); Ps – saturation point (lx).

thalli exhibit a lower rate of gas exchange than annual species with filamentous and thin-layer thalli (King & Schramm 1976; Latała 1982, 1990).

The compensation point was generally in the range of 100–200 lx with a maximum of 350 lx, while photosynthesis was saturated at 1,000–2,000 lx. These results correspond to those reported by Górski (1962) for shade-tolerant plants. According to him, such plants exhibit a compensation point in the range of 100–300 lx and saturation at up to 2,000 lx. Light requirements of algae in the Hornsund fiord are thus typical for shade-tolerant plants and the algae may be considered to be adapted to the special conditions of a habitat where light is an important limitation factor.

In the high Arctic Lund (1959) and Wilce (1967) have found resident populations of perennial algae at depths exceeding 100 m. Only very little light can penetrate to this depth in the high Arctic and in addition, the water masses are by no means very clear. They suggested facultative heterotrophy as a mode of adaptation to this environment. This possibility cannot be ruled out, but it seems that small light requirements might explain to a large extent the presence of Arctic algae at great depths.

The higher light intensities (up to 28 klx) did not have a significant influence on the gas exchange rates of the species examined. Only in one species of green algae, *Acrosiphonia duriuscula*, was a pronounced decrease of photosynthetic rate with increasing light intensity observed.

As shown in Table 1, the results obtained for Spitsbergen algae are basically similar to those reported by Prahl (1979) for Greenland algae. He found that the maximum photosynthetic and respiration rates of six algal species (three of them were the same as in the present paper) were in the range of 0.19–1.25 and 0.03–2.03 $\mu l\ O_2 * h^{-1} * mg^{-1}$ for photosynthesis and respiration, respectively. In this investigation Prahl used Clark's oxygen electrodes. It should thus be noted that despite different methods applied in both studies, the results obtained show great similarity. However, the light requirements of Greenland algae show considerable differences compared with those of Spitsbergen algae. In the case of Greenland species the compensation point ranged widely, e.g. from 300 to 3,500 lx, and was much higher than in the Hornsund species. Photosynthesis was also saturated at very high light intensities, e.g. 10–70 klx. These differences might result from the fact that in the two studies the amounts of algal material used for measurements were not the same. In the case of Greenland algae the gas exchange measurements were performed with much more material, causing mutual shading of the thalli. A second important factor might be the fact that the light regime in the Hornsund fiord is less favourable because of its higher latitude, 77°N, which is much further north than that of Disco Island (69°15′N).

Because the methods of measurement were the same, it is interesting to compare the results obtained in the present work with earlier data on algae from Gdańsk Bay (Latała 1982, 1990). In algae from Gdańsk Bay in temperature 5°C the maximum photosynthesis and respiration rates were 0.21–1.81 and 0.096–0.495 $\mu l\ O_2 * h^{-1} * mg^{-1}$, respectively (Table 1). These values are higher than those for algae in the Hornsund fiord, which suggests that Arctic algae exhibit a lower photosynthetic rate than species from temperate regions. Light requirements of benthic algae from Gdańsk Bay are also higher. The compensation point was 150–900 lx (mainly c. 400 lx) and photosynthesis was saturated at 1,500–7,000 lx. These results additionally confirm the shadow tolerant nature of Spitsbergen algae.

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