On a Complication in Marine Productivity Work due to the Influence of Ultraviolet Light

By

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Introduction

The influence of ultraviolet light on plankton algae is considerable. As reviewed by GESSNER (1955) the long wave-length component part of ultraviolet light is slightly utilized in photosynthesis. However, the ecologically important effects of ultraviolet light on plankton algae are due to adverse influences, such as bleaching of the chlorophyll.

At the surface of the sea the ultraviolet light coming from the sun has wave-lengths between about 310 and 375 mμ. The vertical penetration is very slight in fresh water and in many coastal waters. This is due to the presence of "yellow matter". According to JERLOV (1953) 50–95% is absorbed per m at 375 mμ and 93–100% at 310 mμ in coastal water. However, in oceanic water far from the coast, only 5–10% is absorbed per m at 375 mμ and 14–20% at 310 mμ. In ocean waters ultraviolet light is of importance at least in a surface layer about 20 m deep.

The influence of ultraviolet light both in terrestrial and aquatic higher plants is especially strong in the specimens adapted to low light intensities, cf. the literature cited by GESSNER (1955). Different species react differently according to experiments by GESSNER and DIEHL (1951), who investigated the destruction of chlorophyll in some plankton algae by the ultraviolet part of sunlight. A culture of *Chlorella* was relatively resistant in comparison with cultures of *Scenedesmus* and *Ankistrodesmus*.

Remarkably little work has been done on the influence of ultraviolet light on plankton algae. The present contribution concerns only a rather special problem, but is of some practical importance for measurements of aquatic primary production.

Experiments

All experiments were made during a stay at Friday Harbor Biological Laboratories, University of Washington, in June–August 1962.

1. Surface water was sampled off the pier of the station on 7. July, at 0800 hr and placed in the dark. At 0930 two flat open containers of glass were each

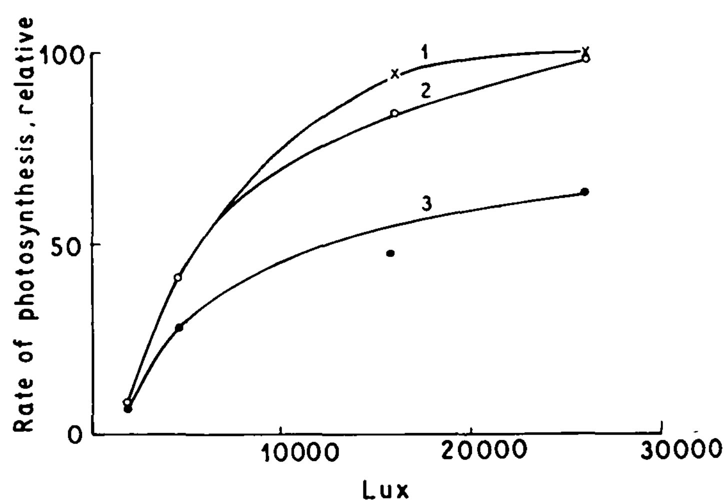

Figure 1. The rate of photosynthesis (relative) as a function of illumination. Surface plankton.
1, after 90 minutes in the dark; 2, after 90 minutes in the sun, but covered with a plate of glass; 3, as 2, but without a plate of glass.

filled with about 350 ml — depth of the water 15 mm — and placed in the sun outside the laboratory on the top of running water from the laboratory salt-water circulation. On the top of one of the containers was placed a plate of clear glass 3 mm thick. The temperature at the start was 12·4°C in both containers. After 90 minutes the temperature had increased to 15·0° in the non-covered container and to 16·0° in the container covered with a glass plate. A third portion of the water was kept in the dark at 12·5°C.

Immediately afterwards, experimental series with the three kinds of water were started in an incubator supplied with running water at 12·5°C. Altogether 10 light bottles and 3 dark bottles were used (50 ml bottles were placed on a rotating wheel). The illumination was produced by means of six 200 watt bulbs with a reflector of aluminium foil behind. The illumination of the individual experimental bottles was varied (1900–26000 lux) by means of Chance neutral glass filters. In principle, although not in detail, the incubator was the same as that descibed by Steemann Nielsen and Hansen (1961). The duration of the experiment in the incubator was two hours.

The rate of photosynthesis was measured by means of the C^{14} technique (Steemann Nielsen, 1952). The individual measurements are corrected for dark fixation. The values are relative, the highest rate of gross production measured being put at 100. Four different light intensities — in addition to dark — were used. Due to the fact that the incubator could only hold 10 light bottles, duplicates could not be made, and only the two highest light intensities could be made in the series with water which had been kept in the dark.

Figure 1 shows that the presence or absence of the 3 mm thick glass plate over the sea water which was illuminated for 90 minutes in sunshine is of decisive importance for the rate of photosynthesis during the next two hours. Both the rate of light saturated photosynthesis and the initial slope of the curve is affected. This is an indication that both enzymes active in photo-

Table 1

Relative rate of photosynthesis in Experiment 2, 20. July 1962 between 1015 and 1500 hr

		Counts per minute	Relative rate of photosynthesis
No filter................	a	492	100
	b	493	
Nylon filter.............	a	777	156
	b	751	
Nylon filter + glass......	a	767	161
	b	798	

synthesis are destroyed and that a part of the chlorophyll is either destroyed or inactivated (cf. STEEMANN NIELSEN, 1962). The results show that the part of the sunlight which is absorbed by a 3 mm thick clear glass plate is able to affect the photosynthetic mechanisms to such a degree that the rate of photosynthesis during a subsequent period decreases considerably. Although some light was lost due to reflection from the glass plate (about 4 %) there is no doubt that the absorption of ultraviolet light in the glass plate caused the difference between the two series.

Figure 1 shows further that the light saturated rate of photosynthesis is only slightly reduced in the water illuminated previously for 90 minutes in the sun but covered with a plate of glass. The rate was only slightly higher in the experiment using water which had been in the dark during the 90 minutes.

2. Surface water was sampled off the pier at 0815 hr (20. July) and kept in the dark til 1015, when six clear bottles with glass stoppers each containing 25 ml were filled with the water to which the content of two C^{14} ampoules was added. All the bottles were placed outside the laboratory in a tray through which water from the laboratory saltwater circulation was running. The whole arrangement was in direct sunlight from 1015 till 1500 hr when the plankton was filtered off by means of a millipore filter HA. The sun was shining from a clear sky throughout the whole experiment. The tray thus received all direct sunlight. The diffused light on the other hand, could only be received from part of the sky — less than 50 %.

Two of the bottles were without cover, and two others were covered with a neutral filter made of black nylon netting absorbing 69 % of the light of all wave-lengths. The last two bottles were also covered vith the black nylon netting, which was, however, placed between two glass plates, each 1·5 mm thick. This filter also absorbed 69 % of the visible light but, in addition, a substantial part of the ultraviolet light. The results are presented in Table 1. The rate of photosynthesis is given as counts/min., not corrected for dark fixation.

The decrease in the illumination to 31 % by means of the nylon netting had the effect that the rate of photosynthesis increased by 56 %. This is in accordance with general experience. The illumination at the actual surface is too high, effecting a decrease of the rate of photosynthesis. The further addition of 3 mm glass had only a slight influence, if any. In another experiment of the same kind, the difference between the bottles with or without glass cover, both with nylon netting, was only one per cent. This indicates that the glass

Table 2

Relative rate of photosynthesis in Experiment 3, 14. July, 1125–1625 hr. Sunshine, except one hour with a cover of white clouds

	Counts per minute		Relative rate of photosynthesis
Nylon filter	a	2171	100
	b	2135	
Nylon filter + glass	a	2586	121
	b	–	
	(the duplicate sample was lost).		

Table 3

Relative rate of photosynthesis in Experiment 4, 15. July, 1415–1700 hr. Alternately cover of white clouds and sunshine

	Counts per minute		Relative rate of photosynthesis
Nylon filter	a	1705	100
	b	1624	
Nylon filter + glass	a	1908	116
	b	1957	

walls of the bottles are able to absorb the ultraviolet light in sunlight adequately if surface plankton is used for the experiments.

However, surface plankton is ordinarily exposed to ultraviolet light and may thus be adapted to such conditions. Plankton from the lower part of the photic zone, where no ultraviolet light penetrates, may on the other hand be expected to be much more sensitive to these wave-lengths. As it was impossible to obtain true subsurface plankton from the vicinity of the laboratory due to the vertical mixing of the water masses, plankton adapted to low light intensities was produced by placing surface water in the incubator at 2000 lux for either two days — Experiment 3 — or three days — Experiment 4. The illumination was given only for about 14 hours every day. During the rest of the day the plankton was kept in the dark.

Experiments 3 and 4 both showed a considerable influence of the glass cover. As might be expected, the influence is highest in Experiment 3 covering 5 hours in the middle of the day with only one hour without direct sunlight. Experiment 4 was made for less than 3 hours in the afternoon with only direct sunlight during half the time. If the light conditions had been the same, we could perhaps have expected the greatest influence of the glass in Experiment 4, the algae here being adapted to a low light intensity, without ultraviolet light, for a longer period.

Discussion

The present experiments show that for algae adapted to low light intensities the glass of the walls of the bottles used was insufficient for filtering the ultraviolet light from the sun, even if 70% of all light, including the ultraviolet part, was previously filtered off by means of black nylon netting. By means of an additional 3 mm glass plate which filters off a substantial part of the ultraviolet light a significant increase in the rate of photosynthesis is effected. It is not possible to decide if a thicker glass plate would have increased the rate of photosynthesis still more.

When using plankton collected from the surface, a plate of 3 mm glass has no or a slight influence only on the rate of photosynthesis if the light is reduced to 30% by means of a neutral filter of nylon netting. Possibly the influence of the ultraviolet light in full sunlight would have been conspicuous. Such experiments were not made.

The experiments had to be made with bottles which were available in the stockroom of the laboratory. The glass — very likely soft glass — of the walls was absolutely clear, and the thickness of the walls was about 2 mm. The special bottles of pyrex glass ordinarily used for productivity work could not be used since they were too large to fit in the available set-up. The results of the experiments are suitable only to give a provisional, although clear, indication that we must take the effect of ultraviolet light into consideration in simulated *in situ* productivity experiments.

Simulated *in situ* experiments are made in a tub on deck. In order to imitate the light conditions at the depths from which the samples were collected, suitable light filters are placed above the bottles containing these samples. If we reduce the light by means of screens of metal, or for example nylon netting, to simulate the conditions at the different depths, we have to consider that ultraviolet light is reduced by such screens only to the same extent as the rays in the other parts of the spectrum. In real *in situ* experiments, on the other hand, ultraviolet light is extinguished more or less completely at the depths with the same intensity of the photosynthetically active light.

Light filters of neutral or coloured glass are very expensive if reliable optical filters are wanted. Neutral filters made by means of screens, for example black nylon, are inexpensive. However, it should be possible to use such cheap filters if sufficiently clear glass is used as an ultraviolet absorbing filter at the same time.

In work on primary productivity in the sea, simulated *in situ* experiments must be considered as a practical technique on many expeditions. If properly made, such experiments are comparable with true *in situ* experiments (cf. BERGE, 1958; JITTS, 1963; STEEMANN NIELSEN, 1964). However, many details have to be considered. One of these details is the influence of ultraviolet light.

Acknowledgement

I am greatly obliged to the Director of the Friday Harbor Laboratories for making my stay possible and for the facilities provided.

Summary

In full sunlight a decrease in the rate of photosynthesis is found both in surface plankton and in dark adapted plankton. If by means of a neutral filter made of black nylon netting the illumination is reduced to 30%, the presence of the ultraviolet part of the light is of no importance for surface plankton

enclosed in ordinary glass bottles. However, in dark adapted plankton the walls of the bottles may not be sufficient to give complete protection against the ultraviolet rays. This is of importance when the simulated *in situ* technique is used for measuring the rate of primary production.

If surface plankton is not enclosed in bottles of glass, the ultraviolet radiation in full sunlight affects the plankton algae in such a way that in subsequent experiments both the rates of the photochemical and the enzymatical partial processes in photosynthesis are reduced. Full sunlight without the ultraviolet part had only a slight influence on the subsequent rate of photosynthesis at all light intensities in surface plankton collected off Friday Harbor.

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